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Process Information Technology: From Research to Industry; Workshop Proceedings

Howard T. Moncarz
Craig Schlenoff
Michael Gruninger
Michael Duffey
Amy Knutilla

U.S. DEPARTMENT OF COMMERCE
Technology Administration
National Institute of Standards
and Technology
Gaithersburg, MD 20899-0001

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ABSTRACT

This report describes a workshop on process information technology (PIT) which was hosted by the National Institute of Standards and Technology on March 12-13, 1998. The workshop brought together vendors, end users, and researchers from different manufacturing-related disciplines to discuss matters of common interest relative to the advancement of PIT. The workshop included presentations from the vendor, research, and user communities. Break-out sessions were conducted to answer a number of questions concerning where the field is going and how the workshop participants would like to influence that direction. Conclusions from the workshop indicate that the PIT market is growing and that it would be worthwhile to coordinate future standards and research activities among the participants as well as other interested parties. This paper documents the proceedings. It includes the summaries of the break-out groups, conclusions and several action items that came out of the workshop, participant information, and presentation slides.

KEY WORDS: PIT; process; process information technology; process specification language; PSL.

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1. INTRODUCTION

The workshop, "Process Information Technology: From Research to Industry," was held on March 12 - 13, 1998 in Gaithersburg, Maryland, under sponsorship of the National Institute of Standards and Technology.

The purpose of the workshop was to bring together vendors, end users, and researchers from different manufacturing-related disciplines to discuss matters of common interest concerning process information technology (PIT). Interest in the advancement of PIT has grown dramatically over the past few years. PIT includes, but is not limited to, process modeling, analysis, execution, and monitoring as well as process information management and exchange. Recent research efforts have focused on identifying and defining the terminology related to manufacturing, enterprise, and workflow processes. The underlying premise is that with a common set of terms, or at least a common meaning of concepts behind those terms, process information will be easier to use, manage, and exchange. With much of this work still in its early stages, NIST hosted this workshop for researchers and practitioners to come together to determine what future directions these efforts should take to ensure they address the needs and challenges that companies are facing today and expect to face in the future.

Appendix A lists the participants and their contact information. Appendix B includes the slides presented at the workshop.

2. OBJECTIVES

The primary objective of the workshop was to provide an open forum for researchers and industry representatives to discuss how current and future research efforts could further address the PIT needs of industry.

Specific workshop goals were:

- to identify, discuss, and propose solutions to issues in current technology with input from vendors, end users, and researchers in the PIT field;
- to raise the awareness of needs in the area of PIT and of current research efforts;
- to determine the need for standards for process information and the role of NIST in that effort; and
- to educate participants by providing an in-depth look at various aspects of PIT.

The workshop included presentations from researchers, vendors, and end users; break-out sessions to address specific needs of researchers, vendors, and users; and a seminar to explore in-depth issues pertaining to the advancement of PIT. The list of presentations is shown in Table 1. The next section presents the results of each of the four break-out groups.

Table 1. Topics presented at the NIST Workshop on Process Information Technology March 12-13, 1998

Presenter	Affiliation	Title of Presentation
Frank Boydstun, Jr	Tinker AFB	Process Knowledge Destinations
Paul Wu	Lucent Technologies	Process Methodology and Tool Standardization—An End User Perspective
Naresh Raja	Deneb Robotics	Industry Collaborative Technology Programs
Kurt Freimuth	Agiltech Inc.	Process Specification Language: A Justification
John Valois	STEPTools, Inc.	Process Information and EXPRESS
Mark Klein	Massachusetts Institute of Technology	Tools for inventing organizations: Toward a handbook of organizational processes
Perakath Benjamin	Knowledge Based Systems, Inc. (KBSI)	Process Information Technology Overview
David Hollingsworth	Workflow Management Coalition	Process Specification & Interchange: A WfMC Perspective
Craig Schlenoff	NIST	Process Specification Language: Overview and Current Status
Anne Jones	Wizdom Systems, Inc.	What we have here is a failure to communicate
Perakath Benjamin	KBSI	Methods and Tools for Process Analysis Presenter
Christopher Menzel	KBSI	Methods and Tools for Process Knowledge Representation and Acquisition
Perakath Benjamin	KBSI	Methods and Tools for Process Design and Implementation
Amit Sheth	University of Georgia	Overview of Workflow Management: Beyond Process Modeling

3. PROCESS INFORMATION TECHNOLOGY ISSUES

The sub-sections below begin with the main question posed and the name of the facilitator for each break-out group.

3.1 Industry Needs and Research Efforts

Question: What are the current and future PIT needs of industry, and are research efforts addressing those needs?

Facilitator: Michael Gruninger

Discussion revolved around the following questions:

- What needs are research efforts currently addressing?
- Which future needs should research efforts address?
- What is the prioritization of these future needs? In particular, which needs are critical in the short and long term?
- What are the major efforts currently underway within the research community?
- What is the mapping between needs and research thrusts?
- How can we facilitate and manage the extraction of needs from industry and communicate them to the research community?

3.1.1 Taxonomy of Needs

The group began by attempting to provide a framework for categorizing industrial needs as a way of matching them to existing research efforts (see Figure 1). The four major categories identified within the group were:

- The industry sector being supported by PIT
- The enterprise function being supported by PIT
- The specific information techology task being supported by PIT
- The motivation and objectives for using PIT

People working within different categories will have different needs with respect to PIT. A more comprehensive framework could possibly be developed and used as a means of extracting requirements from industry.

3.1.2 What's Missing in Current Research

Since we can only model what we can describe, much of the discussion focussed on the problem of the limited expressiveness of existing approaches to process modelling.

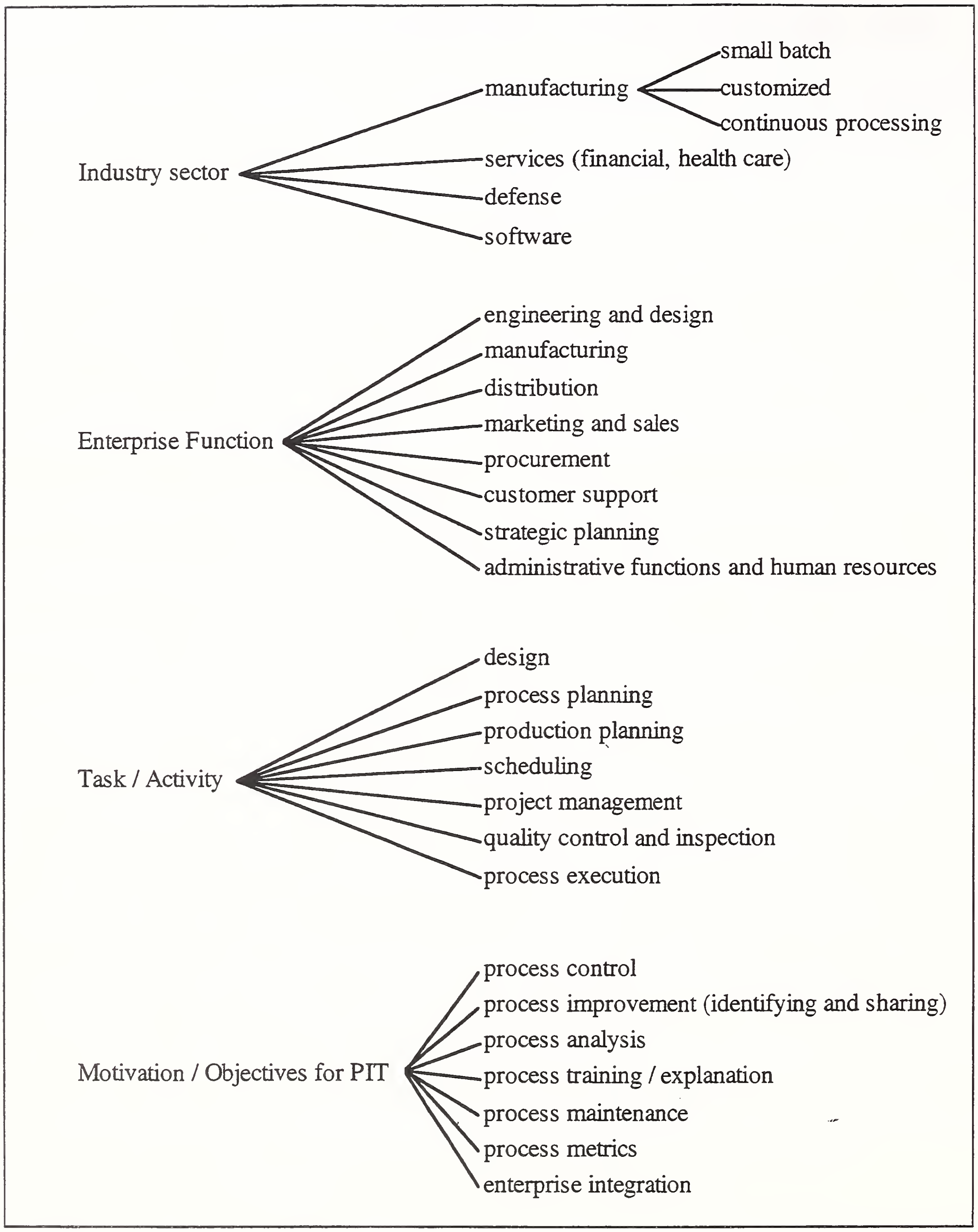

Figure 1: Taxonomy of PIT Industrial Needs

Soft Processes

Much research to date has focused on the tangible aspects of process design and analysis. But it has not adequately addressed the "people" side of the enterprise. Process technology must support the integration of organizations from the perspectives of people, organizational structure, processes, technology, and culture. This requires the ability to model and characterize soft concepts (such as social dynamics), as well as taking an interactive/collaborative approach to the current structural approach for process definition. Furthermore, there needs to be additional work in the specification and measurement of qualitative metrics for processes.

Unstructured Environments

Although many process-modeling formalisms are very good at specifying predictable, deterministic processes, they often fail to capture the rich complexity of the practical world, particularly the ubiquity of non-determinism, unpredictable dynamics, and uncertainty. In particular, formalisms must be able to model unstructured environments with numerous (possibly unknown) variables. The modeler often does not know what stimuli are relevant or when they will occur. An interesting issue is the role of exception handling—current approaches deal with anticipated exceptions, but an even greater challenge will be an account of handling unanticipated exceptions.

Process Intent

Little work has been done on the representation of process intent or rationale. This work is necessary for a proper integration of different process-modeling tools. An example is the relationship between the product designers and the process planners. The features of the product are the intended effects of the process plan, and if any aspect of the product design is changed, the process planners will need to know which activities within the process plan need to be modified.

Lack of Integration

Existing process models are often loosely decoupled from the planning goals and constraints, as well as resource models. In addition, we need better integration between planning models and execution environments (the gap between planning and how the process actually works).

Abstraction

We need models that operate at multiple levels of abstraction, particularly to support planning and execution.

Change Management

We need a better understanding of change management—the migration from "as is" to "to-be" process designs.

Science of Process Modelling

A common theme throughout the discussion was the recognition of the need for a science and engineering discipline for process modeling. Such a science would emphasize the discovery of the underlying principles for process design and analysis, for example, specifying the principles that can be used to achieve enterprise integration.

3.1.3 Research Efforts

The following research projects reflect the participants in the working group; it is not an attempt to be a comprehensive review of current research projects for PIT.

KBSI

Knowledge Based Systems, Inc. (KBSI) is currently working on software tools to support process knowledge acquisition, process design (particularly for virtual enterprises), and the integration of process modeling and analysis. In addition, KBSI is working on foundational semantics for process modeling, i.e., Enhanced Process Interchange Format (EPIF).

How does this work address the above needs? Generic tools are applied to manufacturing and business processes, but they are weaker on services and control. Some soft issues are addressed by acquisition work. Overall, KBSI is moving towards enterprise integration.

Process Handbook

The goal of the Process Handbook project of the Massachusetts Institute of Technology is to help organizations redesign their existing processes and to "invent" new organizational processes. The Process Handbook supports the design of new processes by composition of simpler ones and specialization from more generic ones. In this way, it approximates soft processes with libraries of "harder" processes. In addition, it forms the basis for an engineering discipline for process modeling by developing new methodologies for representing and codifying the organizational processes.

MAVE

Metrics for Agile Virtual Enterprises (a National Science Foundation project) is making promising steps towards "soft logic" using situation theory as an approach to the science of enterprise and process modeling.

TOVE

The TOVE (Toronto Virtual Enterprise) ontologies constitute an integrated enterprise model, providing support for more powerful reasoning in problems that require the interaction of multiple ontologies through the development of foundational theories based on the situation calculus. This framework provides a characterization of classes of enterprises by sets of assumptions over their processes, goals, and organization constraints. Classes of enterprises characterized in this way include material flow (manufacturing supply chains), project management, and business processes.

3.1.4 Collaborative Projects

A number of collaborative projects are underway in both industry and the research communities. Interestingly, most of the following projects are concerned with integration and interoperability.

- Process Specification Language (PSL)
    - *http://www.nist.gov/psl/*
- Process Interchange Format (PIF)
    - *http://ccs.mit.edu/pif*

- Workflow Management Coalition (WfMC)
    - *http://www.aiim.org/wfmc*
- Shared Planning and Activity Representation (SPAR)
    - *http://www.aiai.ed.ac.uk:80/~arpi/spar/*
- International Committee for Enterprise Modeling Technology (ICEIMT)
    - *http://www.mel.nist.gov/workshop/iceimt97/*
- Global Manufacturing in the 21st Century (Globeman 21)
    - *http://ims.toyo-eng.co.jp/gm21/gm21.htm*
- ATP1 (health care)
    - *http://www.hiiatp1.com*

3.1.5 Summary for Breakout-Group 1

Communication is needed in two directions—from industry to the research community and vice versa. In the first direction, there is a need to facilitate and manage the extraction of industry needs and to communicate those to the research community. One possible method is a WWW-based clearinghouse of issues, structured as a taxonomy of industry needs. (A taxonomy was proposed in the break-out session and is shown in Figure 1: Taxonomy of PIT Industrial Needs.)

In the other direction, there is a need to facilitate the transfer of new process technology from the research community to industry so that research results make an impact on industry practice. Furthermore, new process technology must be presented in a form that is easy to integrate with existing software tools and architectures.

Included in this direction is a means of providing feedback to the research community on how well the results are matching industrial problems. For example, much of the discussion in the break-out group focused on the limited expressiveness of current formalisms for process modeling. Industry must identify aspects of their problems that can serve as challenges to evaluate and extend the expressiveness of current formalisms proposed by researchers.

The discussion also highlighted the need for better coordination among projects within the research community and support for reusing the results of groups working in different domains.

3.2 Role of Research

Question: Are the issues being faced by researchers in different fields within PIT aligned and how can these researchers best work together?

Facilitator: Michael Duffey

3.2.1 Alignment of Theory-Related Issues by PSL Researchers

The participants in this group agreed that there had been significant progress in the past year in the theoretical foundations of PSL. Especially noteworthy was the alignment among participants for the approach (e.g., building ontologies) and a common terminology/nomenclature. This was no easy task, given the quite disparate backgrounds of PSL participants in many different industry and academic domains. Much consensus has also been achieved between the PSL and the PIF

communities in terms of language definition, with each group considering extensions that suit their own purposes and are unlikely to cause later conflict. There is still a clear need, however, to

improve communication with EXPRESS [1], Workflow [2], ARPA Rome Planning [3], and other standards research communities. Lastly, it is clear to the group that development of PSL is an intensely interdisciplinary problem. The gap between the "theory-based" participants and the "applied-engineering" participants is still large. A central role for the next PSL phase should be how to improve communication between these two.

3.2.2 Alignment of Scope-Related Issues in the PSL Community

Regarding domain aspects of the scope of PSL, the group agreed that there is still some confusion over whether PSL encompasses

- "Small M" manufacturing (physical fabrication processes);
- "Large M" manufacturing (concept-delivery processes for discrete manufacturing); or
- Business processes in a larger sense.

Much of the discussion and PSL examples focus on "small M." Inclusion of at least "large M" is implicit in the PSL requirements document and is in great demand in industry. The last (business processes in a larger sense) is an obvious extension of "large M" that is already taking place within manufacturing-based corporate environments. Participants agreed that, despite its many limitations, process understanding in manufacturing businesses is much more mature than most other businesses.

3.2.3 Alignment of Goals in the PSL Community

Perceptions of alignment for the goals of PSL varied considerably among members of the break-out group. Exchange of process data between legacy systems, and for emerging software environments, is probably the most tangible and immediate goal. An analogy was made with interoperability efforts in the computer-aided design (CAD) community using international specifications such as the Initial Graphics Exchange Specification (IGES) [4] and the Standard for the Exchange of Product Model Data (STEP) [5]. However, this issue should not be seen just as computer-interoperable process data exchange. A very broad industry need for process data exchange was cited for product-life-cycle data shared between large corporations and their many subcontractors and suppliers. At this time, almost all companies, large and small, have their own internal nomenclature and flowchart descriptors for defining product-development stages between concept and delivery. These unique representations create interoperability problems when development teams have to coordinate meetings and exchange written documents among multiple subcontractor participants.

Beyond the exchange/interoperability issue, it is not clear how priorities should be set for other PSL-related goals, and further prioritization will definitely impact how and which PSL participants will work together. Among the diverse goals cited were:

- Metrics on measuring efficiency of a process;
- Development of a tool to "sell" process to upper management;
- Improved diagrammatic representation of process;
- Ability to elicit and codify processes in a predictable, repeatable way.

Industry participants in this break-out group also reaffirmed that hierarchical decomposition and multiple viewpoints of process are serious problems to be addressed. One company was cited that has six levels of process description, each coming from different legacy/historical contexts with substantial differences between descriptors/terminology. Regarding multiple viewpoints, some differences are legacy-driven, some improvement is possible, but there will always be differences that will not go away.

3.2.4 Mechanisms to Improve Alignment Among PSL Participants

One concern was that the "voice of the PSL customer" needs further refinement, and a customer-requirements document would be very useful. The industry input so far is mostly process-related software developers, not the end-users of process information. While the initial PSL technical report from NIST was cited as a good start, it is still very limited as a customer requirements document. It was suggested that the Malcolm Baldridge National Quality Award[1] might be a good place to start identifying forward-thinking companies to involve in the next phase of PSL development.

Another useful mechanism discussed for the next phase of PSL would be a clearly defined path towards "standardization." What is the NIST role as a broker between customer and vendor? What should the relationship be with respect to PSL issues between the U.S. and global communities? Is there a role for the International Organization for Standardization (ISO)? How will conflict resolution and change management be handled? While it is premature to answer these in detail, some general outline of a standardization path would be useful.

3.3 Role of Standards

Question: What is the role of standards in advancing the state of the art of PIT?

Facilitator: Amy Knutilla

Discussion in this group revolved around the following questions:

- What role are process information standards playing today?
- What role should they play?
- What are the other related standards activities, and how can these work synergistically?
- What is the relationship between product standards and process standards?

The discussion began by questioning our primary question, recognizing that standards typically do not play a role in advancing the state-of-the-art of technology. The primary question was revised to, "what is the role of standards in exchanging process information?" The following focus questions were added:

- Are the current standards adequate to address the scope for which they are designed?
- Are the current standards used?

While these questions were not addressed and answered individually, they served to guide the overall discussion.

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[1] The purpose of the Award is to promote quality awareness and to publicize successful quality strategies. For more information refer to the Uniform Resource Locator (URL): http://www.quality.nist.gov/

3.3.1 Current Related Standards and Standards Activities

This break-out group first identified, to the best of their collective knowledge, current related standards and standards activities. These are listed below (along with brief comments):

- Workflow Management Coalition (WfMC)—generic elements of process plus domain-specific characteristics
- ISO 10303 (commonly known as STEP) Application Protocol (AP) 213 [6] and Part 49 [7]—Computer-Aided Process Planning (CAPP) to Computer-Aided Manufacturing (CAM) interoperability
- MANDATE (ISO 15531 - Industrial manufacturing management data) (has limited U.S. presence)
- EXPRESS 2 [9]—allows for process modeling
- TC29 WG34 (ISO) 13399 [10]—cutting tool resources (Will functional aspects of tool performance be included in the future?)
- Process Interchange Format (PIF)—interchange format under development for business processes
- STEP AP 224 [11] and AP 214 [12] (Are other STEP APs applicable?)
- Process Plan APs
- Object Management Group (OMG)
- Product Data Management (PDM)
- Workflow RFP
- Manufacturing RFPII Release for Production (Routing)
- Process Specification Language (PSL)—neutral representation of manufacturing processes used for exchange

3.3.2 Summary for Breakout-Group 3

Each standard serves a unique purpose. Addressing the challenge of exchanging process information necessitates that process exchange standards work together. Stated another way, no single process standard for exchange is ubiquitous. There need not be competing standards.

It is important to focus on the problems to be addressed in order to enable the exchange of process information in the manufacturing domain. Standards must specify both semantics and a vocabulary, i.e., defining semantics requires a vocabulary. Standards must recognize the existence of multiple scopes and aspects (views) of an exchange; e.g., an exchange may involve process and other types of information such as product, design, and resource information. Part of the standard must address how to "certify" or "validate" interoperability and to assure conformance to the meaning of the information to be exchanged.

This break-out group had a brief and inconclusive discussion on the different models for standards development. The "industry route" of developing and adopting *de facto* standards can be relatively fast and effective, yet there are concerns that smaller vendors can get left out. The formal route, e.g. ISO, offers a useful amount of validity and recognition, but is typically too slow in today's environment.

3.4 Role of Industry

Question: How can industry play a stronger role in setting the direction for current and future research efforts in PIT?

Facilitator: David Hollingsworth

For the purpose of this working group, "industry" was defined as PIT vendors, as well as the users (i.e., customers) of the technology. Furthermore, it was decided that setting the direction of research efforts should be appropriately confined to public research centers (i.e., academic and government research centers). It was suggested that NIST would be an appropriate organization to provide a coordination role with industry and public research organizations involved in the PIT field.

The group believed that it was in industry's interest to take an active role. Industry would benefit because PIT vendors could leverage the research results to produce better products. The users would benefit if the research efforts included activities to disseminate the knowledge about PIT to industry at large—including the users. In the other direction, incorporating user feedback into the developing PIT effort would enable more customer-oriented products to be developed. Together, these communication efforts could help the whole PIT field by helping to grow the market.

Today, unfortunately, industry does not play a sufficient role to help set PIT research directions. Only a minimal effort is expended and only a small number of companies are involved. Instead, participation is needed in a wide range of roles. Industry should help define the general problem statement—to identify and define the technical issues, to document the existing practices, and to propose and promote a vision for the future. Industry should participate in standards bodies, review panels, and user groups. In addition, industry should review PIT-research results and provide feedback to the researchers.

Barriers to more active industry participation include the money required, the availability of people, short term needs versus long-term vision, and lack of a shared understanding of the vision and issues. Industry should help provide the vision and help identify the issues. Widespread dissemination and ultimate sharing of the vision and issues can help overcome the barriers. In addition, letters of support—both to NIST from industry to influence project selection and from NIST to industry to show appreciation for their participation—can be very helpful. Finally, marketing the vision to industry management will also be useful.

4. SUMMARY/CONCLUSIONS

The primary goal of the PIT Workshop was to provide an open forum for researchers and industry representatives to discuss how current and future research efforts could further address the PIT needs of industry. This goal was achieved through presentations from representatives from the research, vendor, and user communities, as well as through the use of break-out group discussions to tackle the tough issues that are facing all of the communities.

Major results from the workshop highlighted the following needs:

- stronger bi-directional communication between industry and the research community to ensure that research efforts are truly addressing the needs of industry;

- better coordination among projects within the research (and standards) community and support for reusing the results of groups working in different domains;
- reduction of the gap between the theoretical aspects and the applied engineering aspects of research efforts;
- clearer description of the scope that the PSL project is addressing;
- clear semantics and syntax in process-related standards;
- certification or validation of interoperability and the assurance of conformance for the meaning of information to be exchanged;
- more active role by industry in standards development in helping to define the general problem statement, participating in standards bodies, review panels, and user groups, by reviewing PIT research results and providing feedback to the researchers, and by providing letters of support to encourage standards work in certain areas.

The action items that came out of the workshop included:

- continued discussion by all participants about the issues presented in the workshop via an email exploder maintained at NIST;
- the creation of web pages containing pointers to existing PIT-related web sites to provide a central point with the most up-to-date information about the PIT field;
- the creation of web pages to provide a version in HTML format of the slides presented at the workshop to other interested colleagues.

ACKNOWLEDGMENTS

The authors thank the break-out group facilitators for providing the information contained here about the discussions and results of the break-out groups.

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[7] ISO, *Product data representation and exchange—Part 49: Integrated generic resources: Process structure and properties*, ISO Standard 10303-49, 1995.

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[11] ISO, *Product data representation and exchange—Part 224: Application Protocol: Mechanical product definition for process plans using machining features*, ISO Standard 10303-224, 1997.

[12] AP214 - ISO, *Product data representation and exchange—Part 214: Application Protocol: Core data for automotive mechanical design processes*, ISO Standard 10303-214, 1997.

Appendix A Final Participants List

William Balko
Wizdom Systems, Inc.
1700 Diagonal Rd.
Alexandria, VA 22314 USA
Telephone: 703/548-7900
Fax: 703/548-7902
Email: wbalko@aol.com

Perakath Benjamin
Knowledge Based Systems
1408 Univ. Dr. East
College Station, TX 77840 USA
Telephone: 409/260-5274
Fax: 409/260-1965
Email: pbenjamin@kbsi.com

Rao Bhamidipati
Xerox Corporation
Fax: 614/793-3514

Frank Boydstun
USAF Oklahoma City
3001 Staff Dr.
Suite 2AG/68A
Tinker AFB, OK 73145 USA
Telephone: 405/736-5567
Fax: 405/736-5431
Email: fboydstu@cdiss1.tinker.af.mil

Ed Braband
Xerox Corporation
317 Main St.
East Rochester, NY 14445 USA
Telephone: 716/264-6764
Email: edward,braband@mc.xerox

Michael Cumming
Carnegie Mellon Univ.
5735 Phillips Ave., Apt. 1
Pittsburgh, PA 15217 USA
Telephone: 412/422-4458
Email: mc9p@andrew.cmu.edu

Alan De Pennington
University of Leeds
School of Mechanical Engineering
Leeds, UK LS2 9JT
Telephone: 0013-233-2113
Fax: 0113-233-2113
Email:adep@leva.leeds.ac.uk

Michael Duffey
George Washington Univ.
Engineering & Applied Science
Washington, DC 20052 USA
Telephone: 202/994-7173
Fax: 202/994-4606
Email: duffey@seas.gwu.edu

David Flater
NIST
Bldg. 220, Rm. A229
Gaithersburg, MD 20899-0001 USA
Telephone: 301/975-3350
Email: david.flater@nist.gov

Kurt Freimuth
AgilTech, Inc.
1111 Edison Dr.
Cincinnati, OH 45011 USA
Telephone: 519/948-2013
Fax: 301/948-2029
Email: freimuth@iams.org

Ted Goranson
Sirius-Beta
1976 Munden Point Rd
Virginia Beach, VA 23457 USA
Telephone: 757/426-6704
Fax: 757/721-0781
Email: tedg@infi.net

Michael Gruninger
University of Toronto
4 Taddle Creek Rd.
Dept. of Mech. &Ind.
Toronto, Ontario, M5S 3G9 CANADA
Telephone: 416/978-6347
Fax: 416/971-2479
Email: gruinger@ie.utoronto.ca

Satyandra Gupta
Carnegie Mellon Univ.
Robotics Institute
5000 Forbis Ave.
Pittsburgh, PA 15213 USA
Telephone: 412/268-8780
Fax: 412/268-5569
Email: skgupta@ri.cmu.edu

Ron Hebron
Boeing
P.O. Box 3707
Seattle, WA 98124 USA
Telephone: 425/865-2793
Fax: 425/865-2966
Email: ronald.l.hebron@boeing.com

David Hollingsworth
ICL Pathway Ltd.
Forest Rd.
Feltham, Middx, TW13 7EJ UK
Telephone: 440/18173041
Fax: 0044-0181-730-4151
Email: david.hollingsworth@fel0152.x400.

John Horst
NIST
Bldg. 220, Rm. B124
Gaithersburg, MD 20899 USA
Telephone: 301/975-3418
Email: john.horst.@nist.gov

Hui-min Huang
NIST
Bldg. 220, Rm. B124
Gaithersburg, MD 20899-0001
Telephone: 301/975-3418
Email: hui-min.huang@nist.gov

Anne Jones
Wizdom Systems, Inc.
1700 Diagonal Rd.
Alexandria, VA 22314 USA
Telephone: 703/548-7900
Fax: 703/548-7902
Email: aej@charm.net

Mark Klein
MIT Ctr. for Coordination Science
Rm. E400-169
1 Amherst St.,
Cambridge, MA 02139 USA
Telephone: 617/253-6796
Fax: 617/253-4424
Email: m_klein@mit.edu
Amy Knutilla
NIST
Bldg. 220, Rm. A127
Gaithersburg, MD 20899-0001 USA
Telephone: 301/975-3514
Email: amy.knutilla@nist.gov

Thomas Kramer
NIST
Bldg. 220, Rm. B124
Gaithersburg, MD 20899-0001 USA
Telephone: 301/975-3418
Email: thomas.kramer@nist.gov

Yuan-Shin Lee
North Carolina State Univ
Dept. of Ind. Eng.
Raleigh, NC 27695 USA
Telephone: 919/515-7195
Fax: 919/515-5281
Email: yslee@eos.ncsu.edu

Richard Mayer
Knowledge Based Systems
1408 Univ. Dr. East
College Station, TX 77840 USA
Telephone: 409/260-5274
Fax: 409/260-1965
Email: rmayer@kbsi.com

Chris Menzel
Knowledge Based Systems
1408 Univ. Dr. East
College Station, TX 77840 USA
Telephone: 409/260-5274
Fax: 409/260-1965
Email: cmenzel@kbis.com

Naresh Raja
Deneb Robotics, Inc.
Auburn Hills, Mi. 48321-4687 USA
Telephone: 248/377-6900
Fax: 248/377-8125
Email: raja@deneb.com

Steven Ray
NIST
Bldg. 220, Rm. A127
Gaithersburg, MD 20899-0001 USA
Telephone: 301/975-3524
Email: steven.ray@nist.gov

Craig Schlenoff
NIST
Bldg. 220, Rm. A127
Gaithersburg, MD 20899-0001 USA
Telephone: 301/975-6536
Email: craig.schlenoff@nist.gov

Harry Scott
NIST
Bldg. 220, Rm. B124
Gaithersburg, MD 20899 USA
Telephone: 301/975-3418
Email: harry.scott@nist.gov

Amit Sheth
University of Georgia
415 Boyd GSRC
LSDIS Lab
Athens, GA 30602 USA
Telephone: 706/542-2310
Fax: 706/542-2966
Email: amit@cs.uga.edu

Debra Stephens
Raytheon Systems Company
50 Apple Hill Dr., M/S T3MJ21
Tewksbury, MA 01876 USA
Telephone: 978/858-5063

Ronald Stogdill
USAF
2977 P St.
Dayton, OH 45433 USA
Telephone: 937/255-7371
Fax: 937/255-4420
Email: stogdill@ml.wpafb.af.mil

Brian Stucke
AFRL Mtls & Manufacturing
2977 P St., Suite 6
Wright-Patterson AFB, OH 45433 USA
Telephone: 937/255-7371
Fax: 937/656-4269
Email: stuckeba@ml.wpafb.af.mil

John Valois
STEP Tools, Inc.
1223 Peoples Ave.
Troy, NY 12180 USA
Telephone: 518/276-2277
Fax: 518/276-8471
Email: valois@steptools.com

Evan Wallace
NIST
Bldg 220, Rm. A229
Gaithersburg, MD 20899-0001 USA
Telephone: 301/975-3520
Email: evan.wallace@nist.gov

Michael Wozny
Rensselaer Polytechnic
Ctr. for Advance Tech.
CII 8015
Troy, NY 12180 USA
Telephone: 518/276-2898
Fax: 518/276-4897
Email: wozny@cat.rpi.edu

Paul Wu
Lucent Technologies
6200 E. Broad St.
Rm. 1H333
Columbus, OH 43213 USA
Telephone: 614/860-5130
Fax: 614/868-2513
Email: paulwu@lucent.com

Bob Young
Loughborough University
Loughborough, Leics, LE11 3TU UK
Fax: 0113-233-2150
Email: adep@leva.leeds.ac.uk

Appendix B Presentations

The workshop presentations follow. For simplicity the numbering system used for each presentation was preserved. Before each presentation is a page that lists the title, the name of the workshop presenter, and a brief biography. The biographies were provided by the presenters with small edits made as necessary.

Some of the slides did not convert very well from color to black and white. For any presentation that is illegible or difficult to read on the hardcopy version provided here, please refer to the web site at http://www.nist.gov/psl/pit/

Process Knowledge Destinations

Frank Boydstun, Jr., Tinker AFB

Mr. Boydstun is the program manager for the Industrial Process Improvement (IPI) Program at the Oklahoma City Air Logistics Center. The OC-ALC is a maintenance and repair depot for Air Force weapon systems, which includes operating the world's largest jet engine overhaul operation and maintaining the B-52 and B-1 Bombers, the KC-135 tanker and variants, and the E-3 AWACS. Since 1991, the IPI program has documented in excess of $2.5M per year savings, with improvements covering the entire spectrum of large and small cultural and technical change.

The primary tools of the IPI program are the IDEF3 method and discrete event simulation with over 350 depot personnel trained in ProSim and over 70 depot personnel trained in WITNESS. Current program effort is to build perpetually validated simulation that feed directly from the raw data of the maintenance information systems.

In addition, Mr. Boydstun works on research and policy efforts with several Air Force Materiel Command (AFMC) organizations including Armstrong Labs, Wright Labs, Logistics Modeling and Simulation group and the Shop Floor Control group.

Mr. Boydstun received bachelor degrees in English and Mechanical Engineering from Oklahoma State University.

Process Knowledge Destinations

Frank Boydstun
OC-ALC/TIE
3001 Staff Drive, Suite 2AG/68A
Tinker AFB OK 73145-3040
comm (405) 736-5567
fax (405) 736-5431
dsn 336-5567
e-mail fboydstu@ocdiss1.tinker.af.mil

OUTLINE

- Depot Maintenance Domain
  - characteristics
  - efforts/philosophy
- Common to ALL Efforts
- Process Knowledge Destinations
- Benefits
- Needs

Maintenance Domain

- Unknown work when work arrives
  - manpower
  - material
- Partial & flexible sequence of work
- Manage access constraints
- Harvest shop floor knowledge
- Continuing iterations of unknown repairs

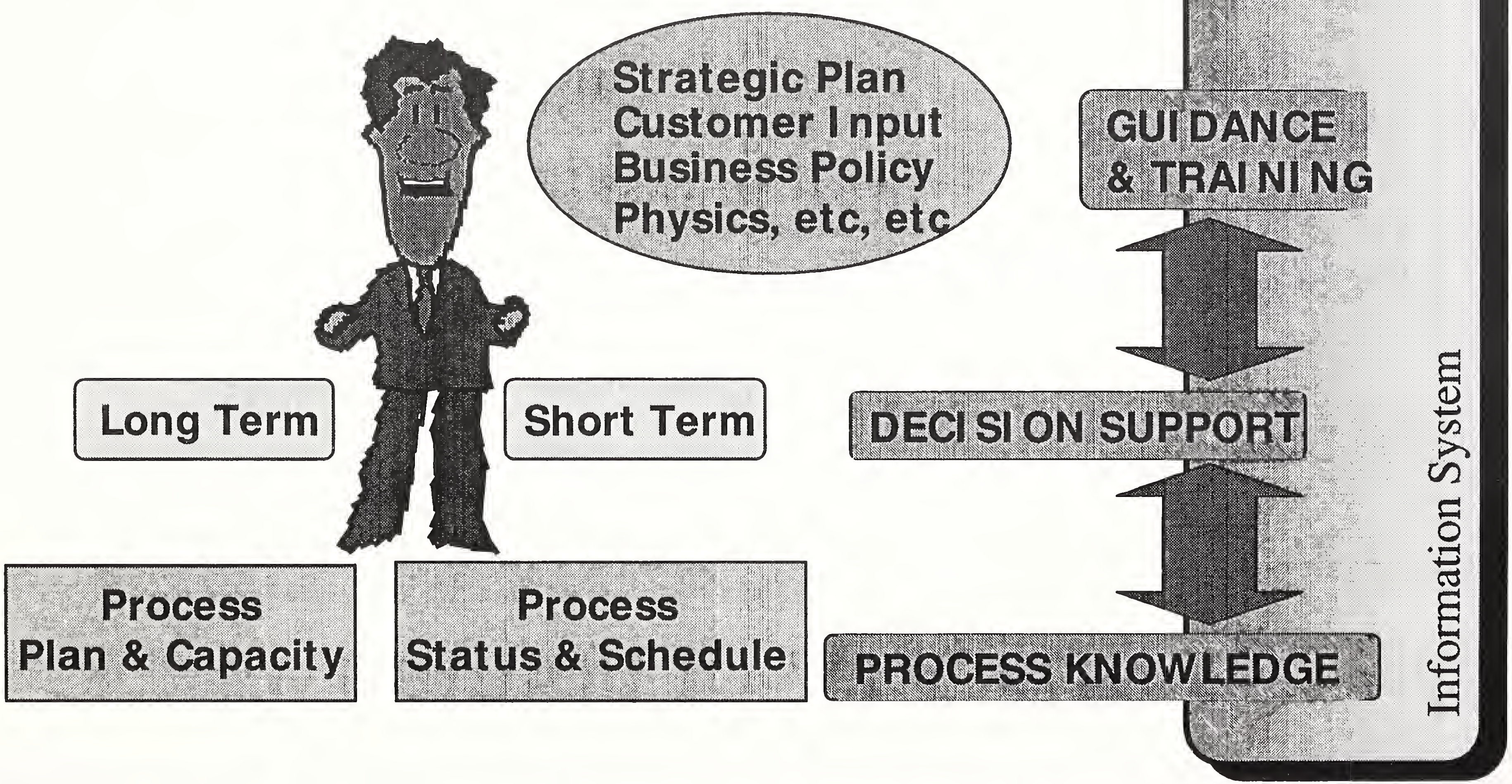
Process Improvement Efforts

- IPI, ‘88
  - AFMC/CC Interest item, ‘93
  - AFMC Reg 500-15, ‘93, rev ‘96
- TQM, ‘88
- SEI CMM, ‘90
- Re-Engineering Teams, ‘94
- Lean Logistics, ‘94
- ISO 9000, ‘95

Common to ALL Efforts

- Answer two questions
  - What is the process?
  - What is the impact of a change on the process?
- Have been using two tools
  - IDEF3, ProSim
  - Stochastic simulation, WITNESS

Process Manager/Worker Needs:



Process Knowledge Destinations

- Analysis
  - evaluate/improve cost/time of process
- Quality
  - evaluate/improve output of process
- Planning/Scheduling
  - estimate/predict requirements/performance
- Training
  - prerequisites, basic, advanced, leading edge
- Information Systems
  - needed from process
  - needed by process
- Day-to-Day Management
  - status/tweak to completion

Two Faces of Process Knowledge

- Towards humanity
  - build consensus of understanding among experts
  - train novices in execution of process
- Towards the computer
  - build applications to support process execution, status, or analysis

Destination Examples

- E3 PDM - prototype planning module with perpetually valid simulation online
- Ogden Annual PDM Workload - raw planning data to project plan and to stochastic simulation
- Pacer Lean Avionics - raw data driven perpetually valid simulation
- ITS training - IDEF3 knowledge to MS Windows Help

Benefits of Process Modeling and Analysis

- Contracted Costs/Returns - $4M/$15M
- Organic Results - 147 improvements over last 3 years
- Pacer Lean Avionics shop has the best ‘metrics’ in the command
- Getting results in 1/2 to 1/3 the time and cost of other technology approaches

Process Technology Needs

- Integrated modeling, analysis, and execution
- Process knowledge repositories for storage, maintenance, and just-in-time delivery of process knowledge
- Integration of process modeling tools with scheduling and statusing systems
- Adaptive, reconfigurable process modeling and analysis tools
  - Tools can be reconfigured easily when requirements change
  - Process reconfigures itself when the process execution performance deteriorates

Process Methodology and Tool Standardization—An End User Perspective

Paul Wu, Lucent Technologies

Dr. Paul Wu is a Senior Consultant of Lucent Technologies (formally AT&T) - Bell Labs. He is a leading expert of process modeling in Bell Labs. He has been a modeling consultant to numerous types of manufacturing/software development systems and to service industries. His recent consulting activities include coordinating the integration of Activity-Based Costing, process description/documentation, and simulation tools into a total solution package; and the enhancement of risk analysis capability in project management. He is working closely with tool vendors, research communities, and standards' organizations in establishing standards of business process management methodologies and tools.

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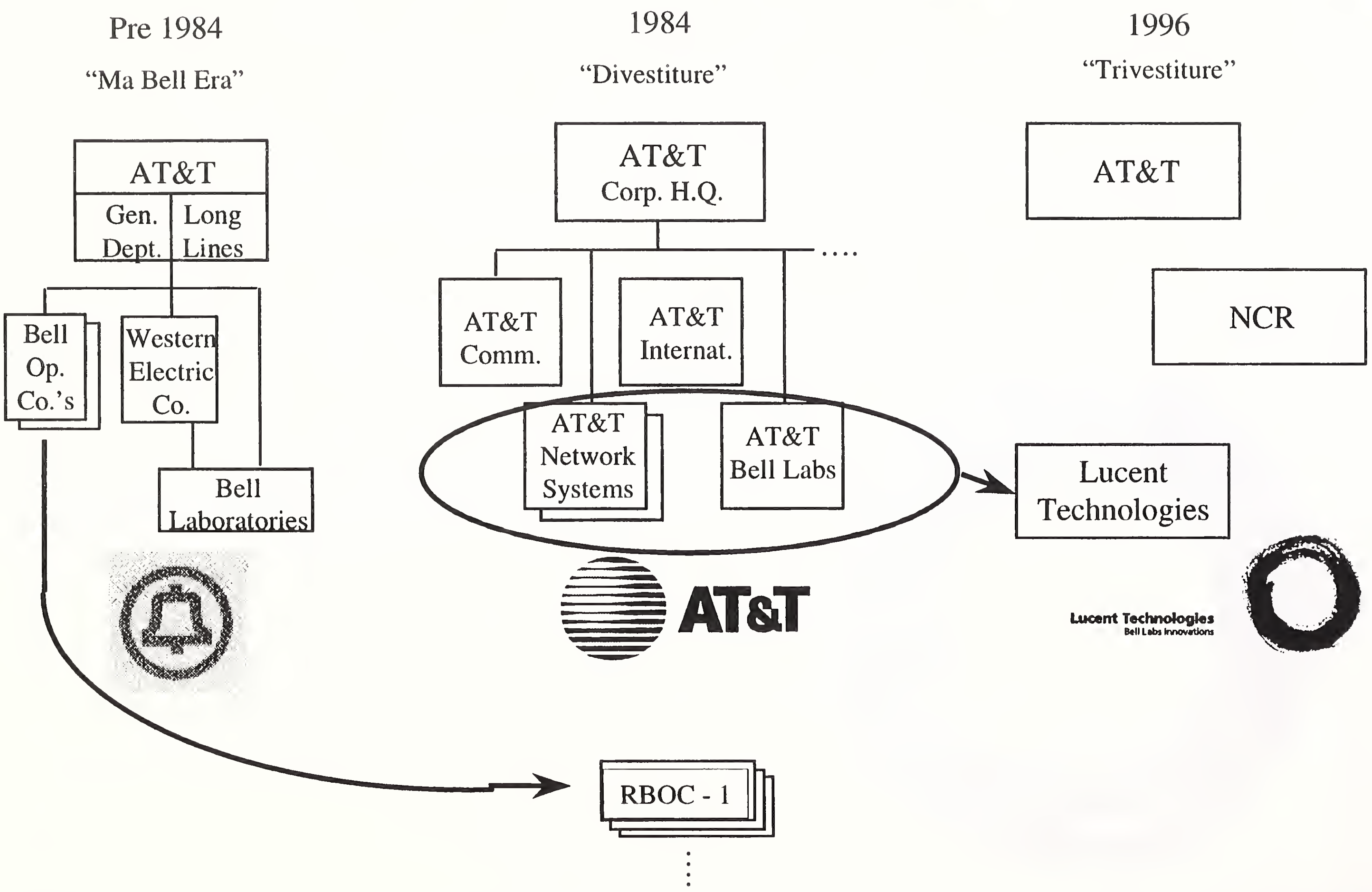
Bell Labs Innovations

Process Methodology and Tool Standardization - An End User Perspective

Paul Wu, Ph.D.

Who We Are


Pre 1984
"Ma Bell Era"
AT&T
Gen. Dept.
Long Lines
Bell Op. Co.'s
Western Electric Co.
Bell Laboratories
1984
"Divestiture"
AT&T Corp. H.Q.
AT&T Comm.
AT&T Internat.
....
AT&T Network Systems
AT&T Bell Labs
AT&T
RBOC - 1
1996
"Trivestiture"
AT&T
NCR
Lucent Technologies
Lucent Technologies
Bell Labs Innovations

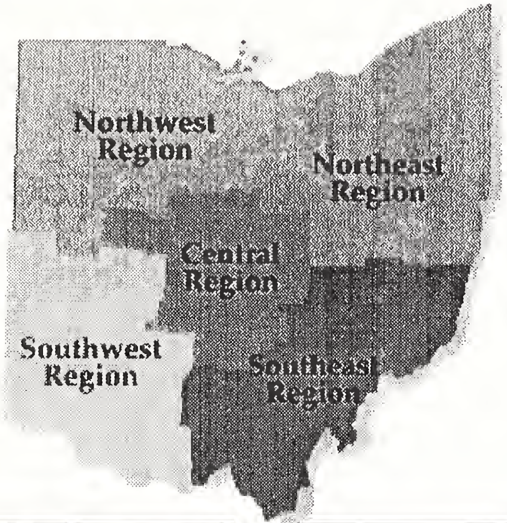
Who We Are

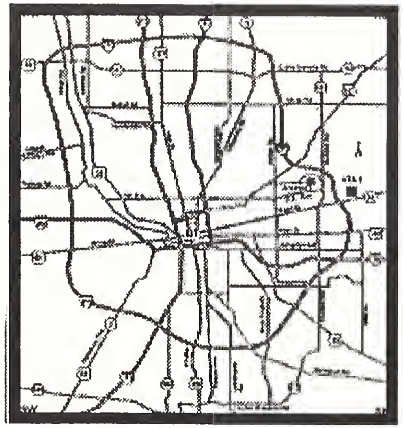
- Lucent Technologies
  - Bell Laboratories
    - Advanced Technologies

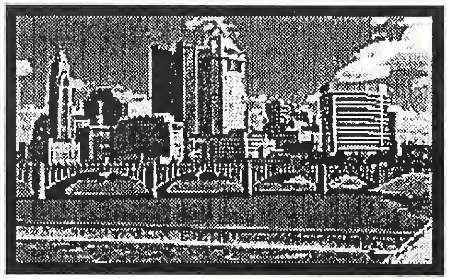
Lucent makes the things that make communications work.

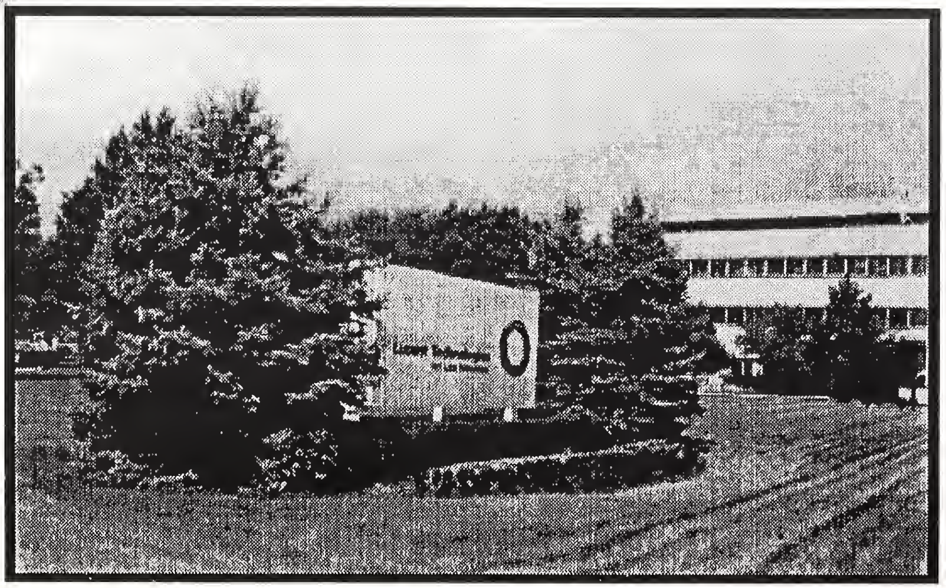
We provide Process Simulation/Modeling Tools and Methodologies supporting Lucent Business Units.

Columbus Works, Columbus, Ohio

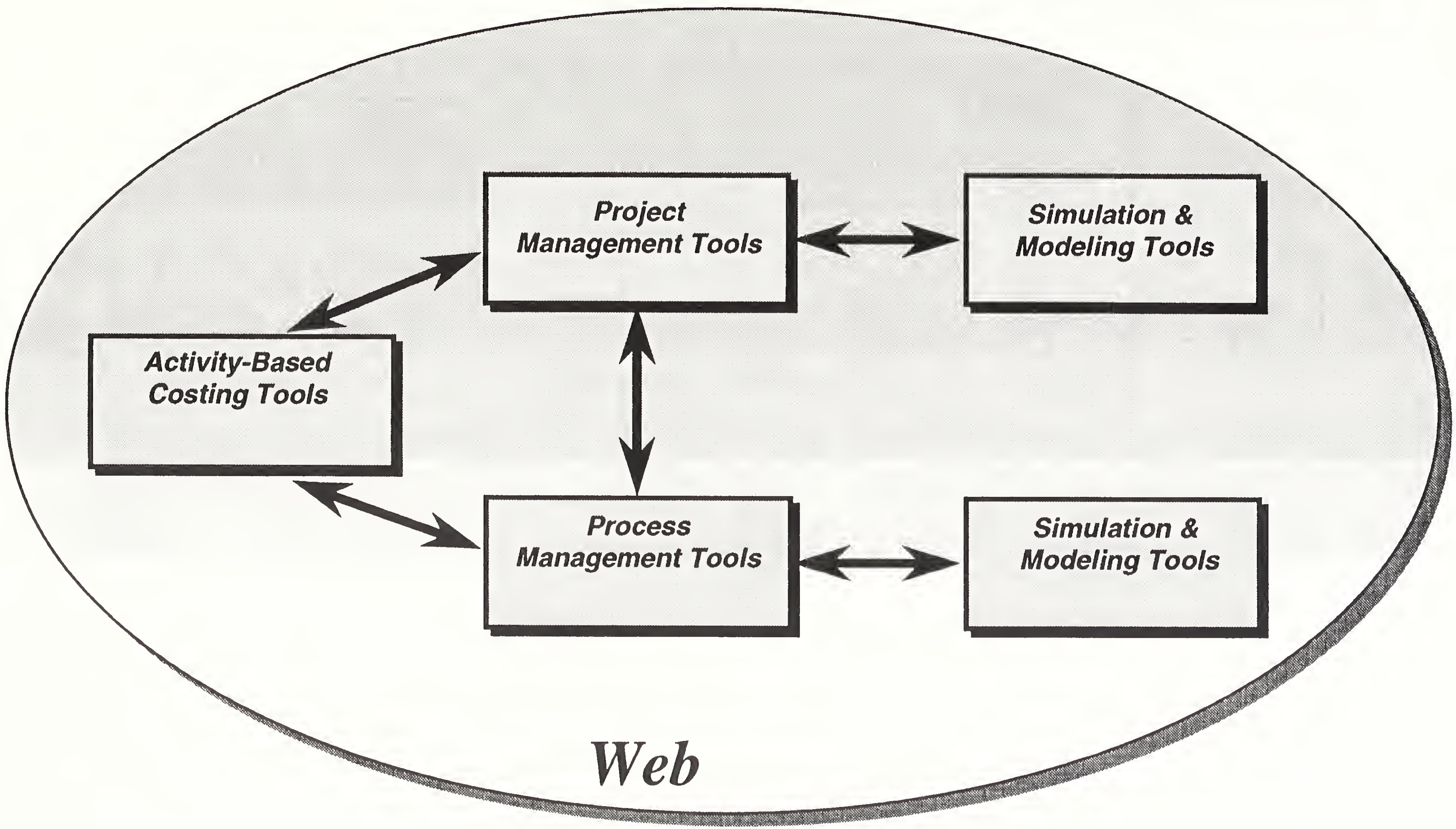








Process Simulation/Modeling Platform - an ideal picture



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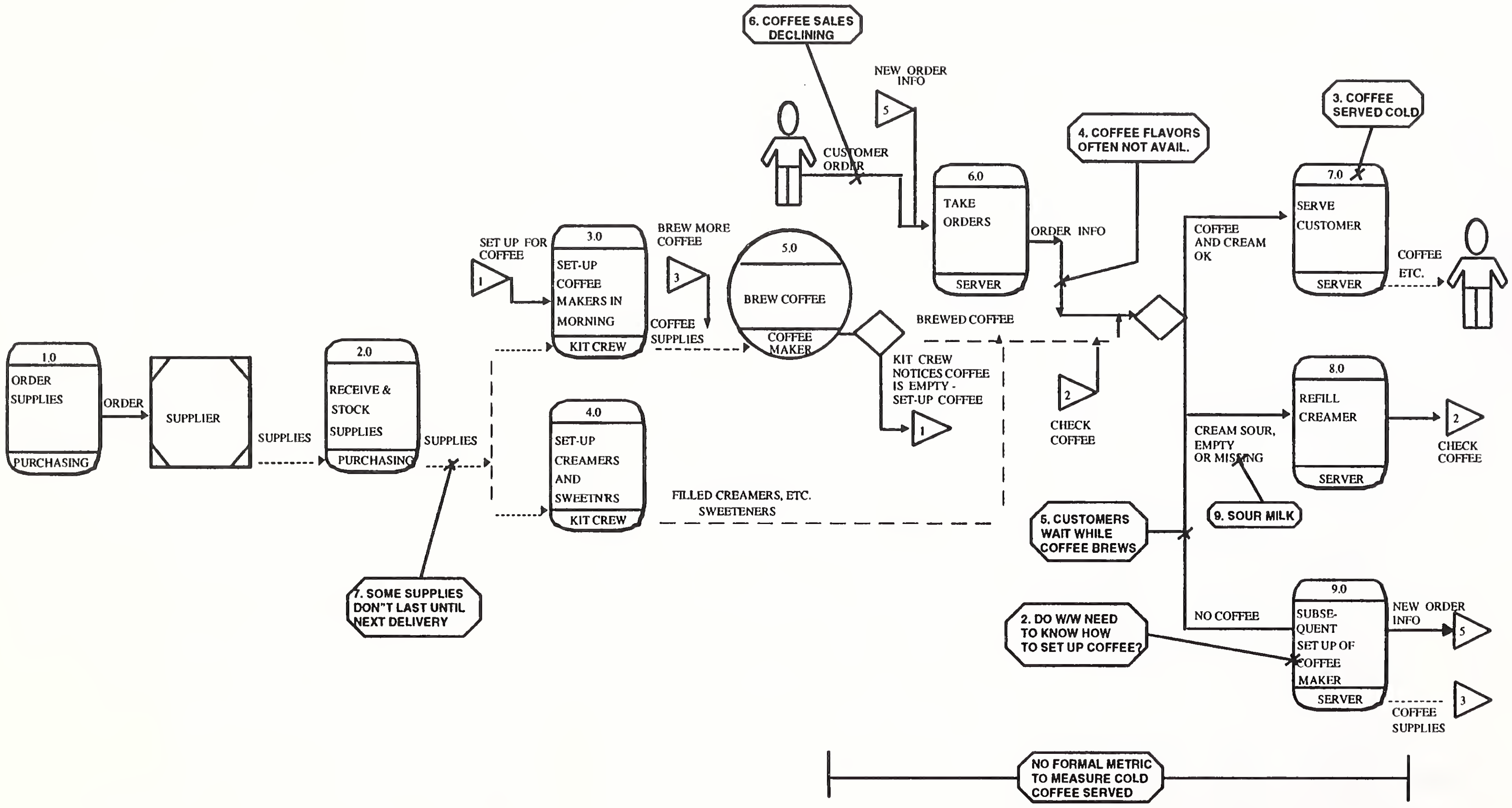
DETAILED BASELINE WITH ISSUES



OEW - Characteristics

- Top-down hierarchical end-to-end view of process
- Left-to-right time sequence
- Clear view of flow of information and materials
- Clear indication of role of computer support systems
- Overall topology of flow doesn't change as hierarchical levels are examined

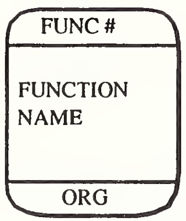
OEW - Application

- OEW Flow Diagramming Technique displays the relationships among functions, systems processes, etc.

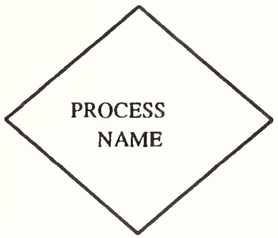
- Allows you to show activities as being serial or in parallel.

- Technique and conventions are NOT intended to show actual or relative intervals, resource availability, or other factors critical for ongoing ***project management***.

OEW - Flow Diagram Symbols



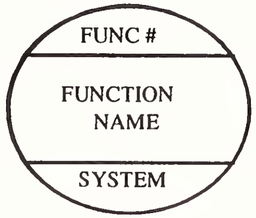
Functions performed by Org. or Work Centers are shown as vertical rectangles with rounded corners dividen into three sections.



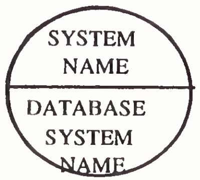
Internal processes are represented by large diamonds with the name of the process written inside.

Processes outside the process to be improved are depicted as diamonds with “cut corners”. The name of the external process is written inside the diamond.

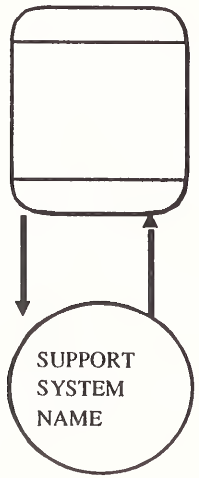
Names of organizations outside the process to be improved (i.e. Vendors and Customers) are shown as squares with “cut corners”.



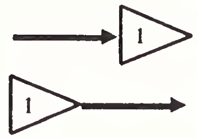
Function performed solely by computer systems are depicted by a circle divided into three areas.



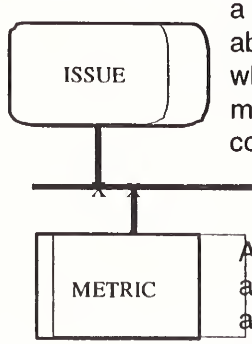
Functions performed by a System with a Database is depicted by a circle divided in half.



Support systems are depicted by a circle containing the name of the information system. This symbol is used when the system is supporting a function.

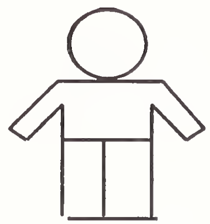


Feedback symbols are used to prevent flowcharts from becoming too cluttered. Feedbacks are always labeled numerically. Identical labels must be given to both ends of the feedback loop.



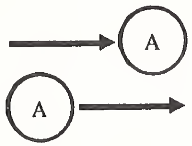
An issue identified within a process is shown in an oval above or below the point at which it occurs. The point is marked by an X and is connected bo the oval by a line.

An metric identified within a process is shown in an square above or below the point at which it occurs. The point is marked by an X and is connected bo the oval by a line.

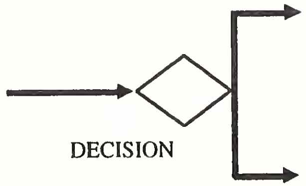


A customer.

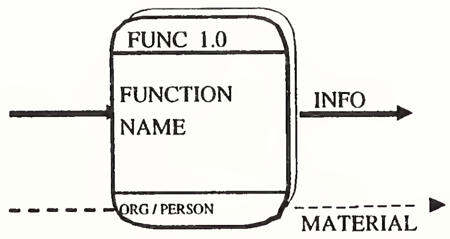
OEW - Flow Diagram Symbols (cont.)



Connector symbols are used to split either on a page or between pages. The symbol is a small circle with a capital letter. The identical letter is given to both sides of the division.

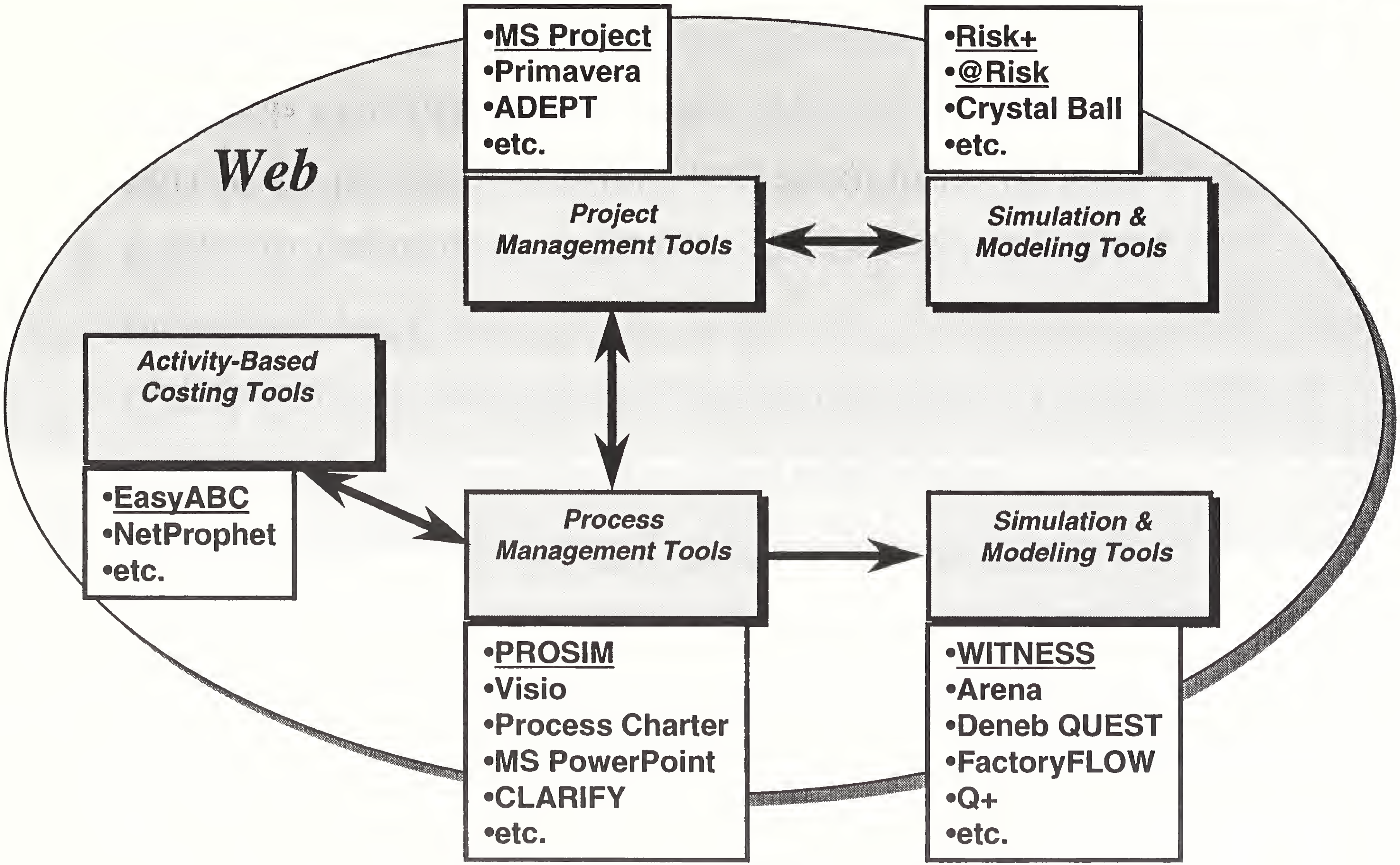


Decision points are shown as small diamonds. These are points at which choices are made based on pre-specified conditions.



Nodes are connected by two types of interfaces. Solid lines through the middle of the node to represent information be handed off from one node to the next, and a dashed line through the lower portion of the node to represent material being handed from one node to the next.

Process Simulation/Modeling Platform - Moments of Truth



Requirements (Audience: Process Engineer) - 1

- Capture of basic process information model entities including work product, task, method, role, tool, skill, training, template, dependency, and parameter
- Prevention of inconsistent input and output
- Capability for new report generation from existing data in process model
- Print out paginated version of the process in whole or part (e.g., by work product and associated process elements) for offline review
- Support for process reuse

Requirements (Audience: Process Engineer) - 2

- Projects should be allowed to customize the process for their project, so they should be allowed to make changes to some extent
- Distributed process maintenance with concurrency-protected database
- Allow process change and version control to support ISO certification. Also allow rolling back to previous versions when needed and allow different groups to work with different process versions
- Generate both general and project-specific project management models from process
- Plausible migration path for current users of other tools

Requirements (Audience: Process Engineer) - 3

- Platform independence for process capture
- Menu-driven/graphic-based/systematic process definition and construction
- User-definable audits
- Need explicit "triggers" for decision points in process
- Several levels of security against inadvertent changes to process

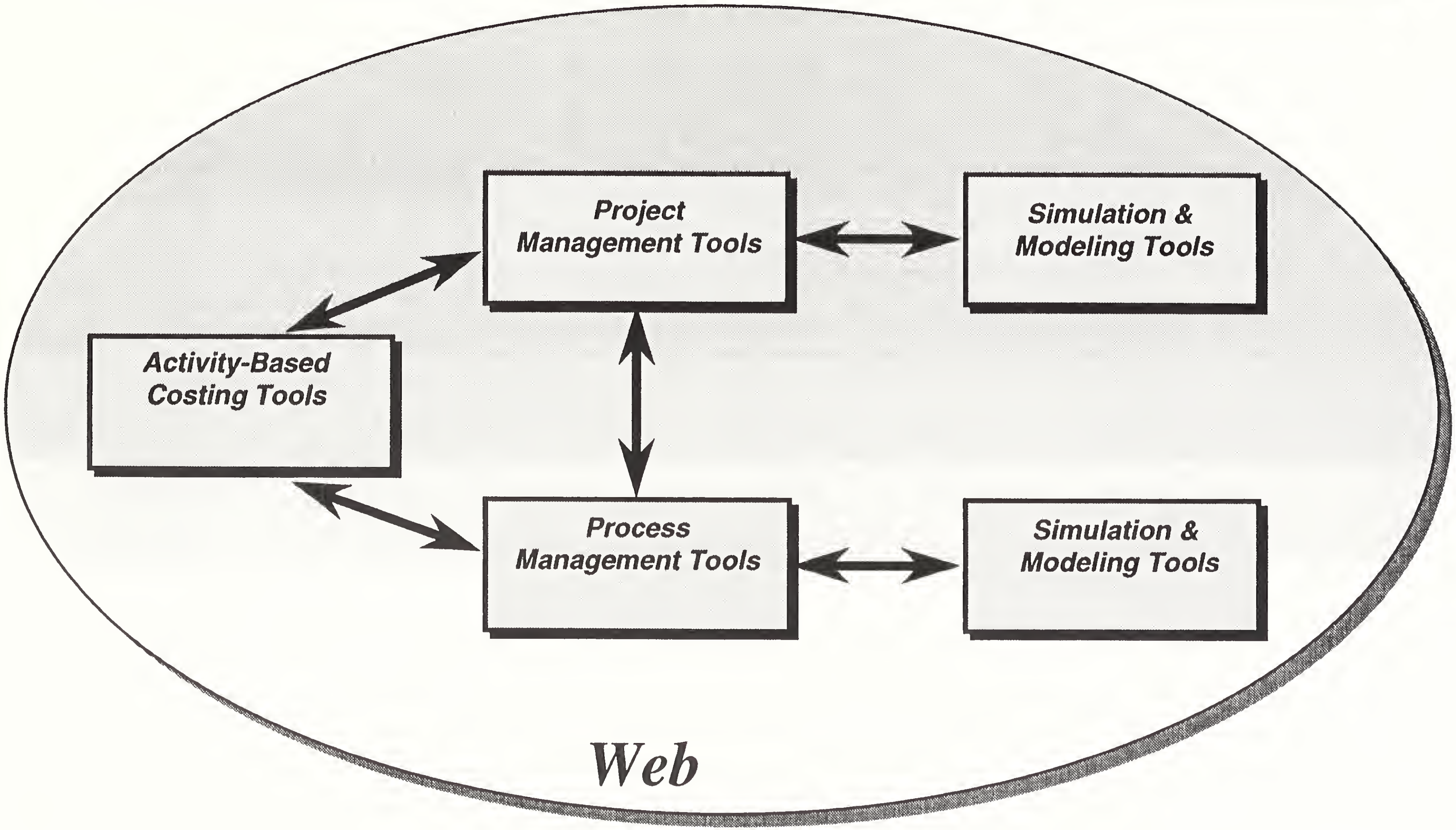
Requirements (Audience: Process User) - 1

- Platform independence for process users' display
- Support for independent and parallel tasks within the same work product
- Immediate online access to changes in process
- Graphical display of process flow routinely available to process users
- Open-ended text search capability

Requirements (Audience: Process User) - 2

- User (Role)-centered process view
- Capability for both work product view and activity-based view
- Easy to run tool

Summary


Project
Management Tools
Simulation &
Modeling Tools
Activity-Based
Costing Tools
Process
Management Tools
Simulation &
Modeling Tools
Web

Industry Collaborative Technology Programs

Naresh Raja, Deneb Robotics

Mr. Raja is currently the Programs Manager at Deneb Robotics and is managing several Defense Advanced Research Projects Agency (DARPA) projects. Prior to this position he was the Support manager for Deneb IGRIP/ENVISION software products for five years. Before 1992 Mr. Raja was a Senior Systems software engineer at Electronic Data Systems (EDS). During his almost nine years at EDS he was responsible for leading and developing many different manufacturing solutions for General Motors' assembly plants and developing CAD/CAM software for off-line programming robots. Before his tenure at EDS, Mr. Raja was at LaSalle Machine Tool Inc. as a manufacturing engineer involved in the design and the production of special purpose machine tools utilizing CAD/CAM software. Mr. Raja's master's thesis involved the application of Group Technology for sheet metal applications.

INDUSTRY COLLABORATIVE TECHNOLOGY PROGRAMS

RaDEO - Rapid Design Exploration and Optimization
- MSD - Manufacturing Simulation Driver

SAVE - Simulation Assessment Validation Environment

Naresh Raja
Programs Manager

Raytheon Electronic Systems

Deneb

LOCKHEED MARTIN

RaDEO - Rapid Design Exploration and Optimization Program

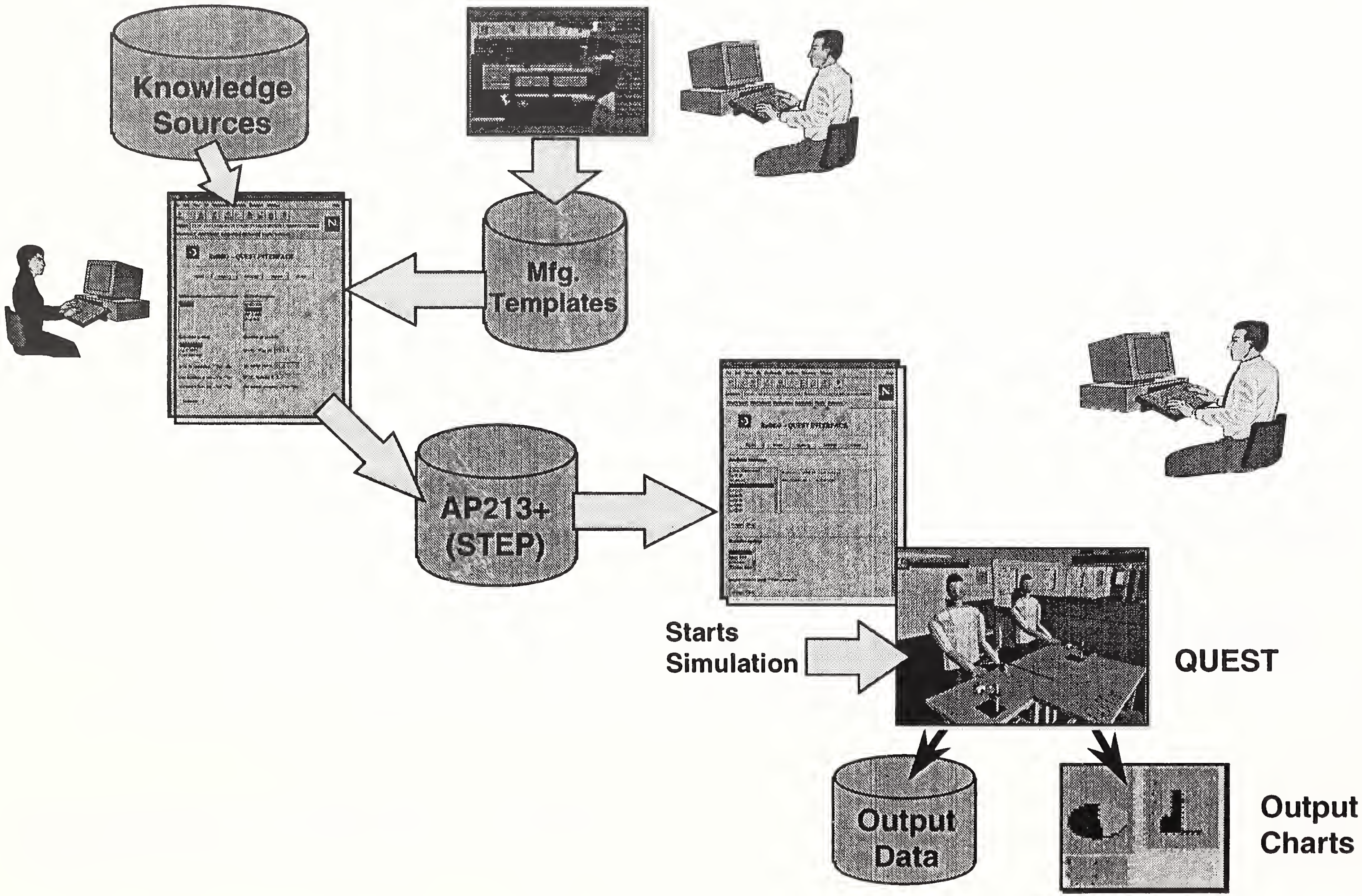
Manufacturing Simulation Driver - Project Goals

- **Develop a standard for a product/process data model which supports manufacturing simulation**
- **Drastically streamline the process of simulation model development, and enable rapid assessment of multiple design and manufacturing scenarios**
- **Develop internet based tools to facilitate the exchange of information, initiation of simulation analysis and feedback of simulation results**
- **Impact the cost and quality of new designs by enabling more rapid and higher fidelity assessments**

MSD - Project Focus

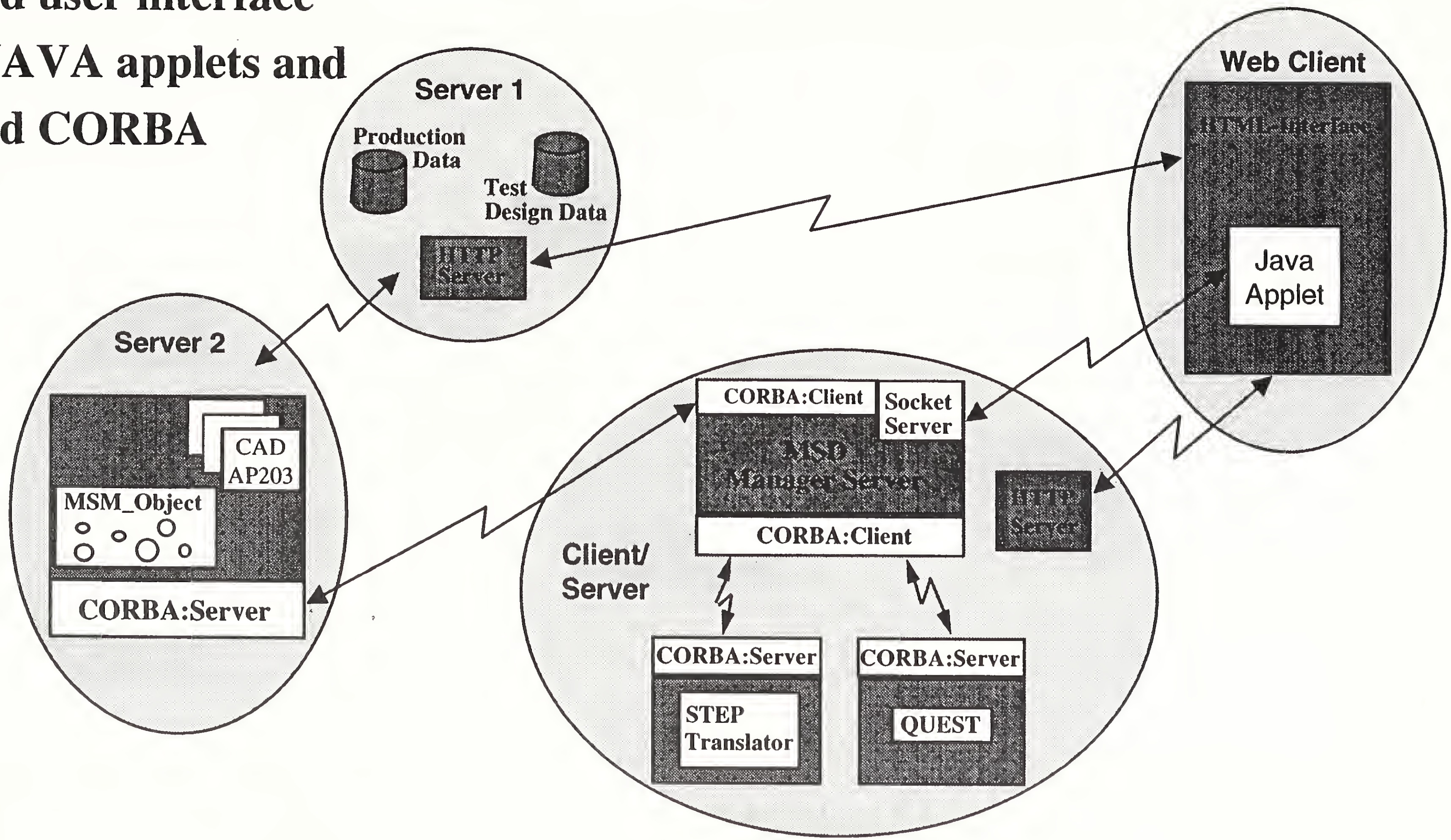
- Use and Extend Existing STEP Standards
  - Define extensions to AP213 process planning entities to add information required for discrete event simulation
  - Use AP203 CAD models for geometric representations during the simulation
- Development of Manufacturing Templates
  - Modular logic which process parts throught the simulation using the extended AP213 model
  - Eliminate part specific information from manufacturing templates
  - Greatly simplifies the creation of new factory templates
- Demonstration of Collaborative Capabilities
  - Using internet, CORBA and JAVA
  - Initiate and manage simulations remotely

Manufacturing Simulation Driver Functional Architecture

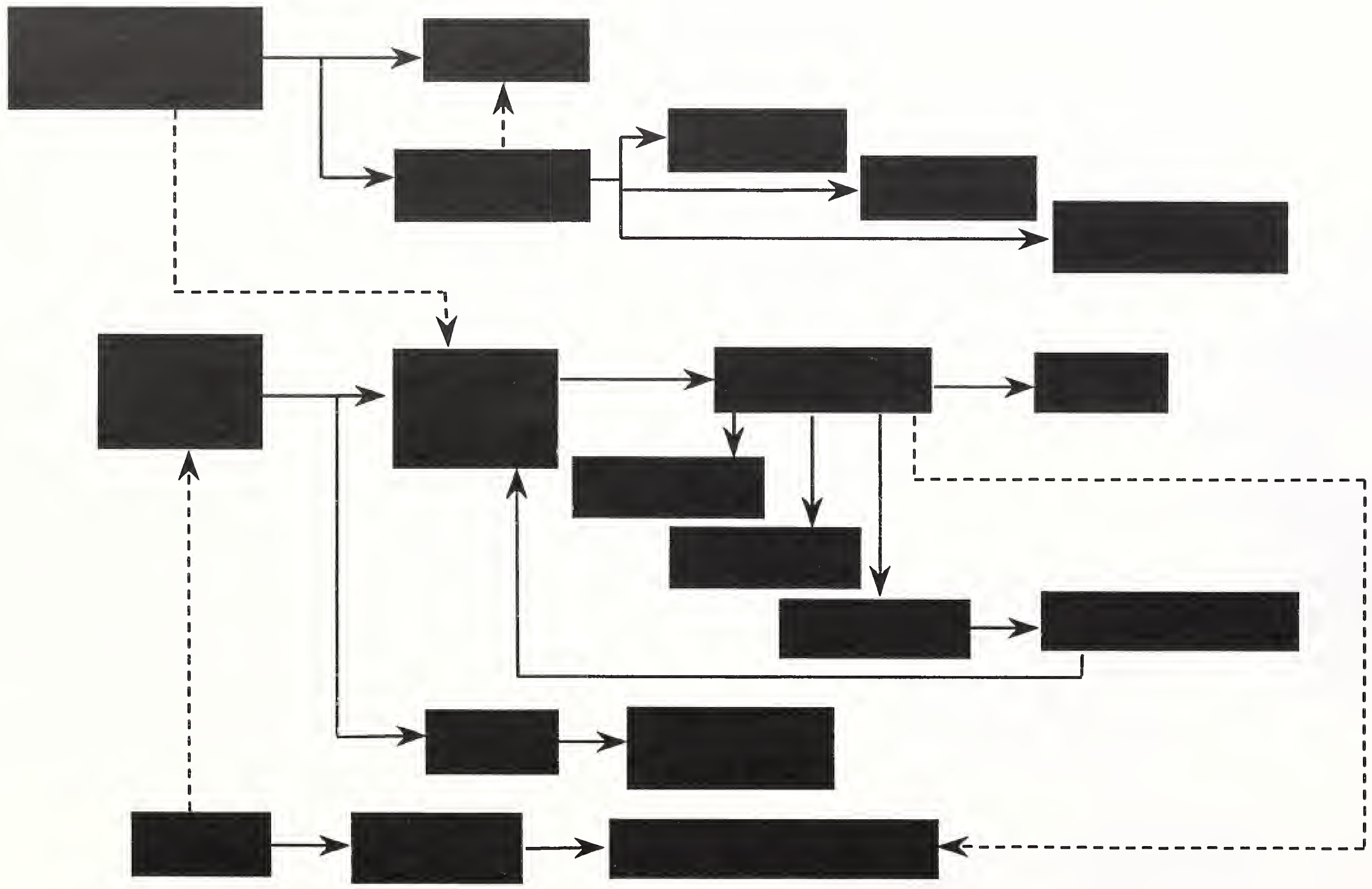


MSD - System Architecture

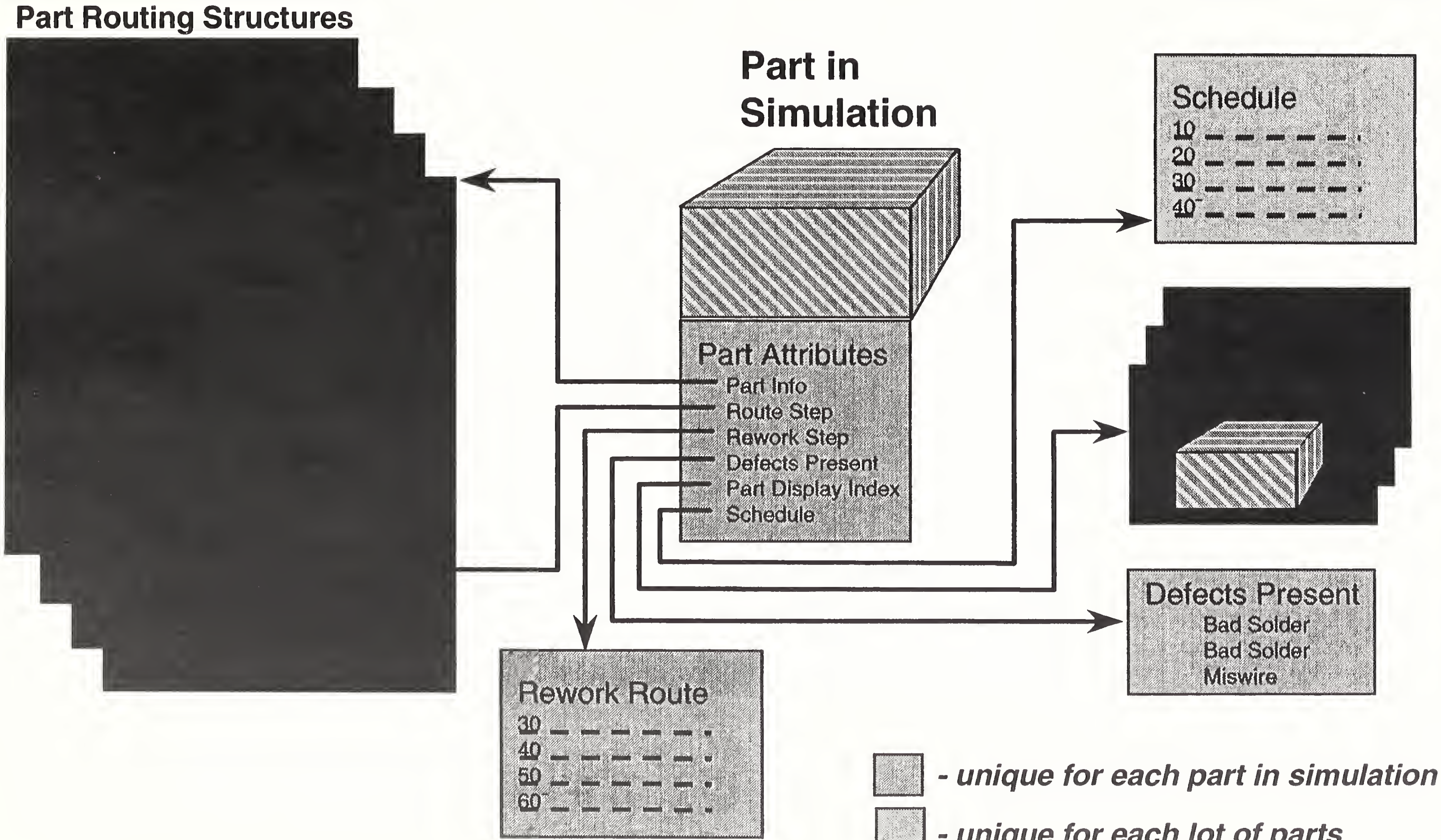
Web based user interface through JAVA applets and distributed CORBA objects



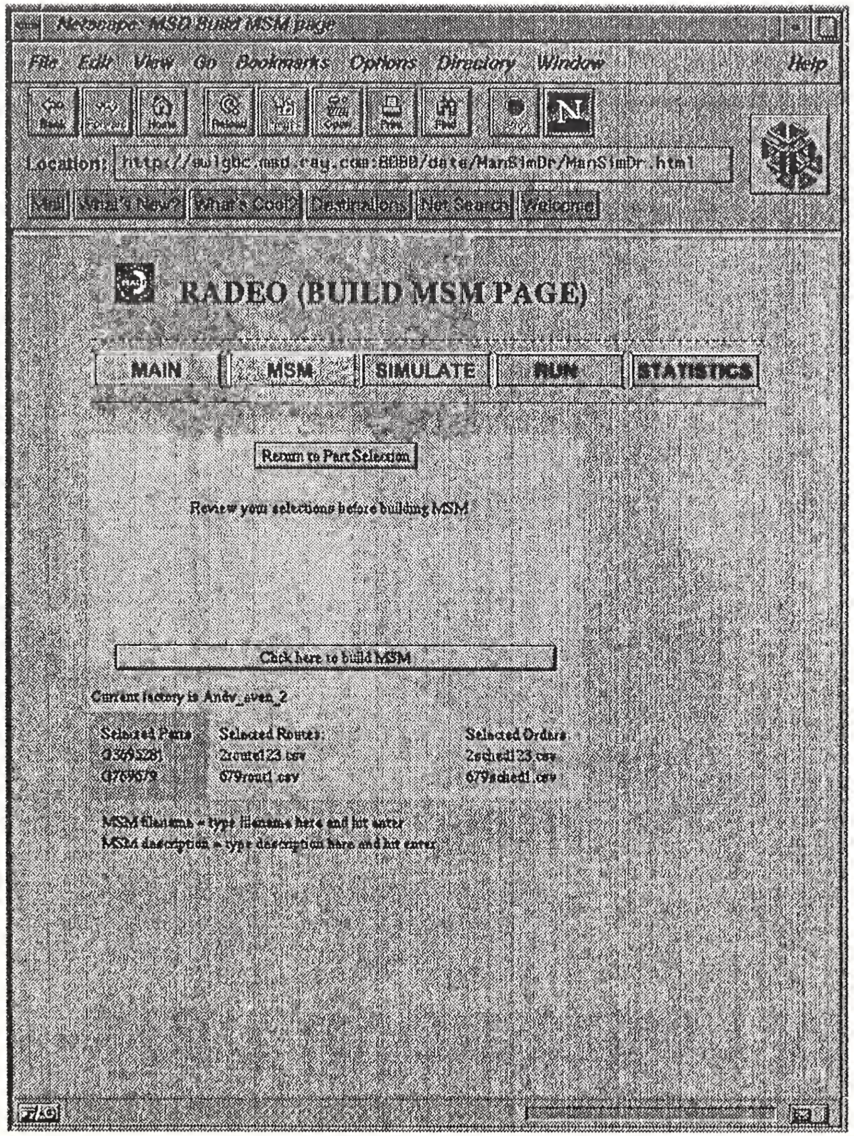
MSD - Simulation Activity Model



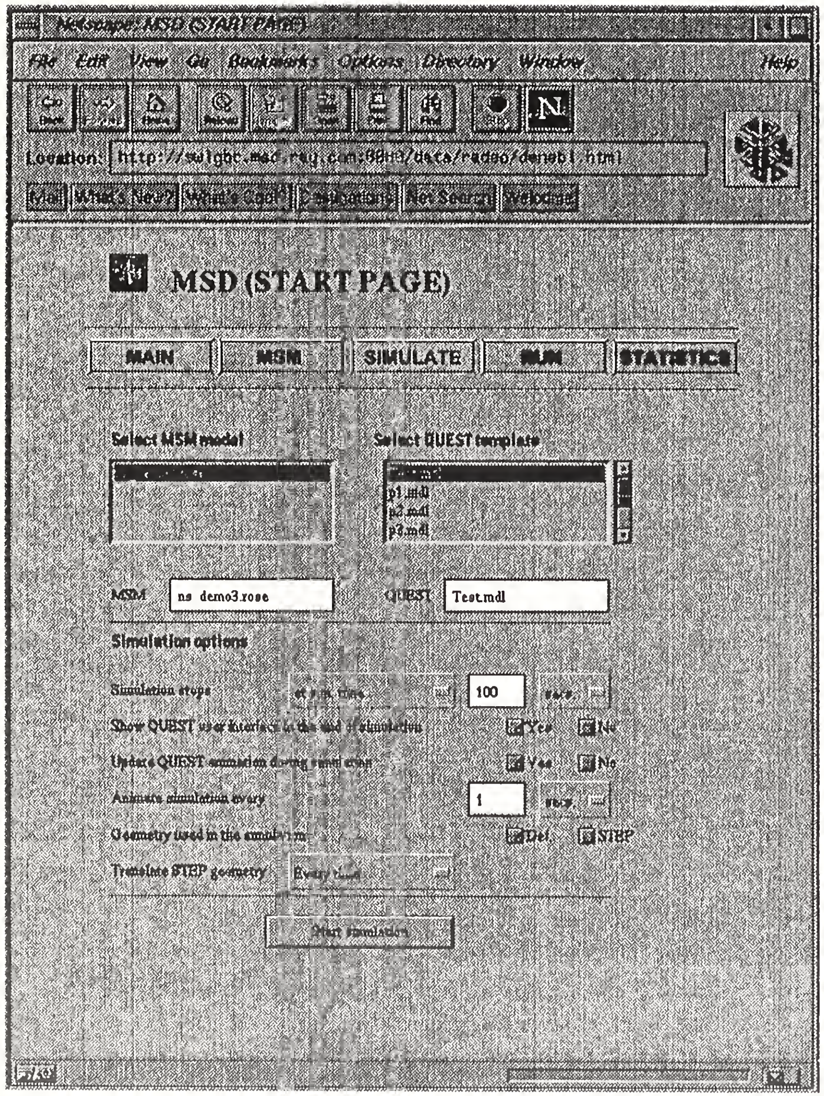
MSD - Part Information Model



MSD - Input To Build AP-213+



MSD - Simulation Inputs



INPUTS

MSM model

Simulation run method

Simulation run time (Optional)

Animation interval

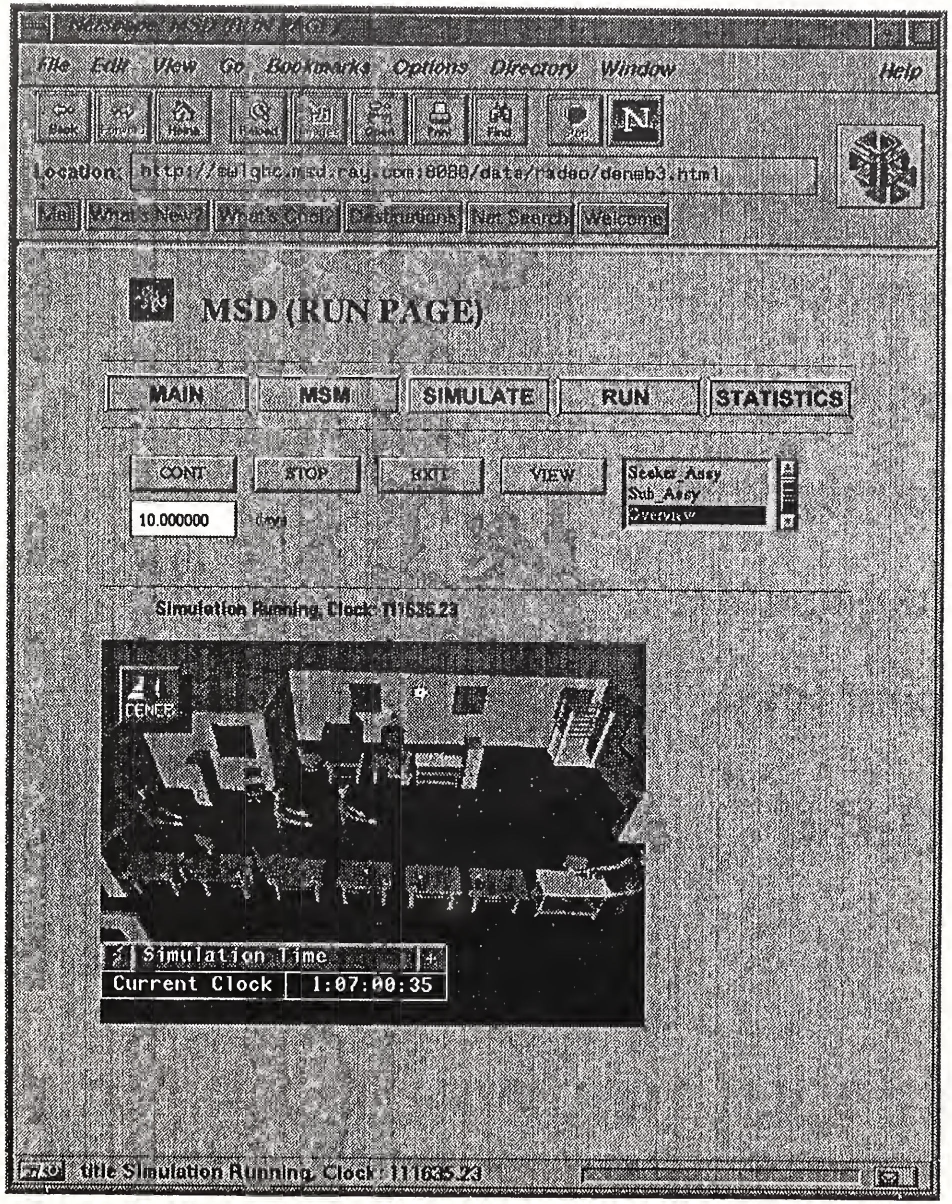
Display of QUEST interface

Picture update interval

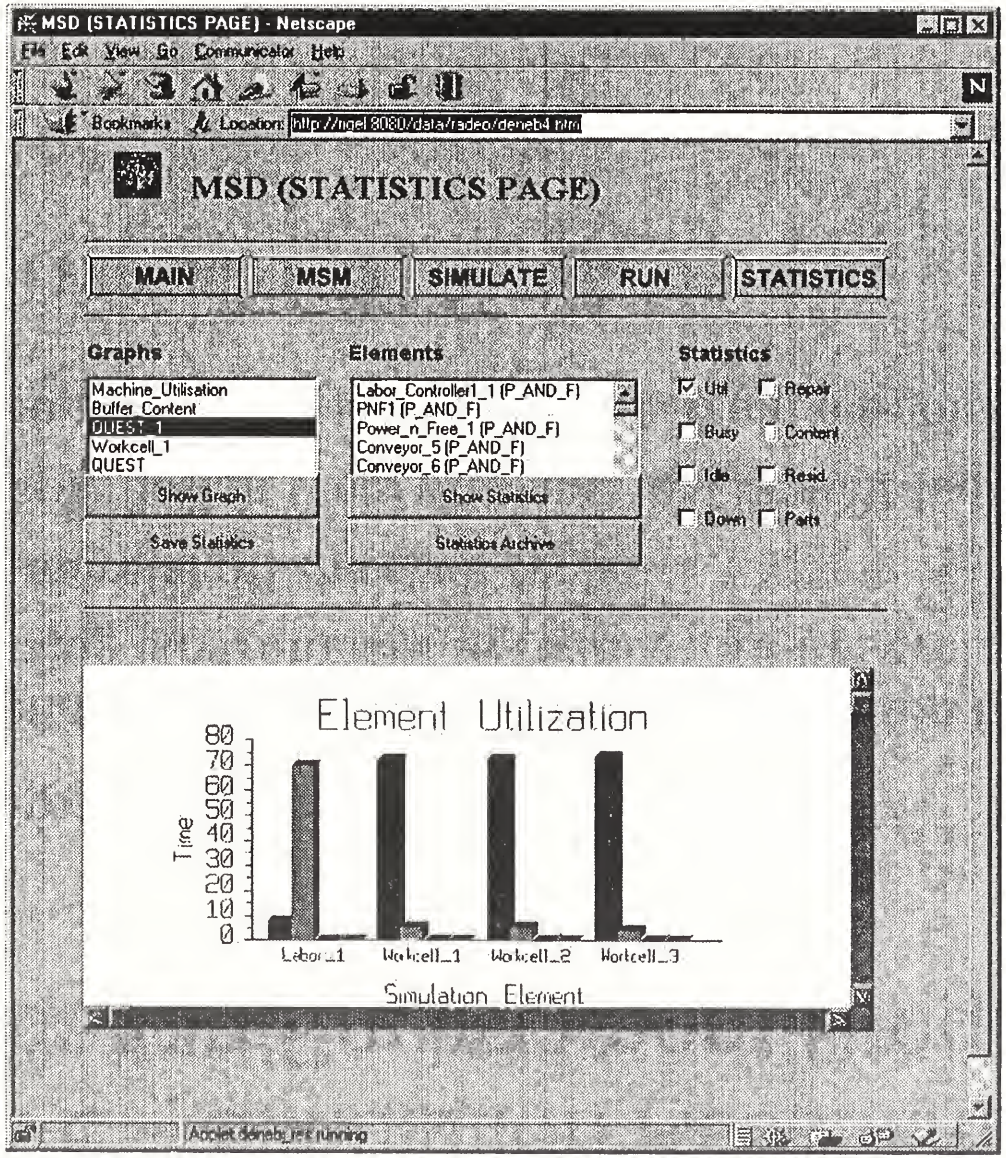
Use of default geometry

Translate STEP geometry

MSD - Simulation Results



MSD - Simulation Statistics



SAVE - Simulation Assessment Validation Environment Program

PROGRAM APPROACH:

- **Integrate and implement modeling and simulation tools into a virtual manufacturing environment to reduce JSF life cycle cost**
- **Apply commercial off the shelf tools**
- **Tightly couple design tools with cost assessment tools**
- **Use emerging integration technologies from on-going DARPA programs**
- **Validate on F-16 and F-22 programs**

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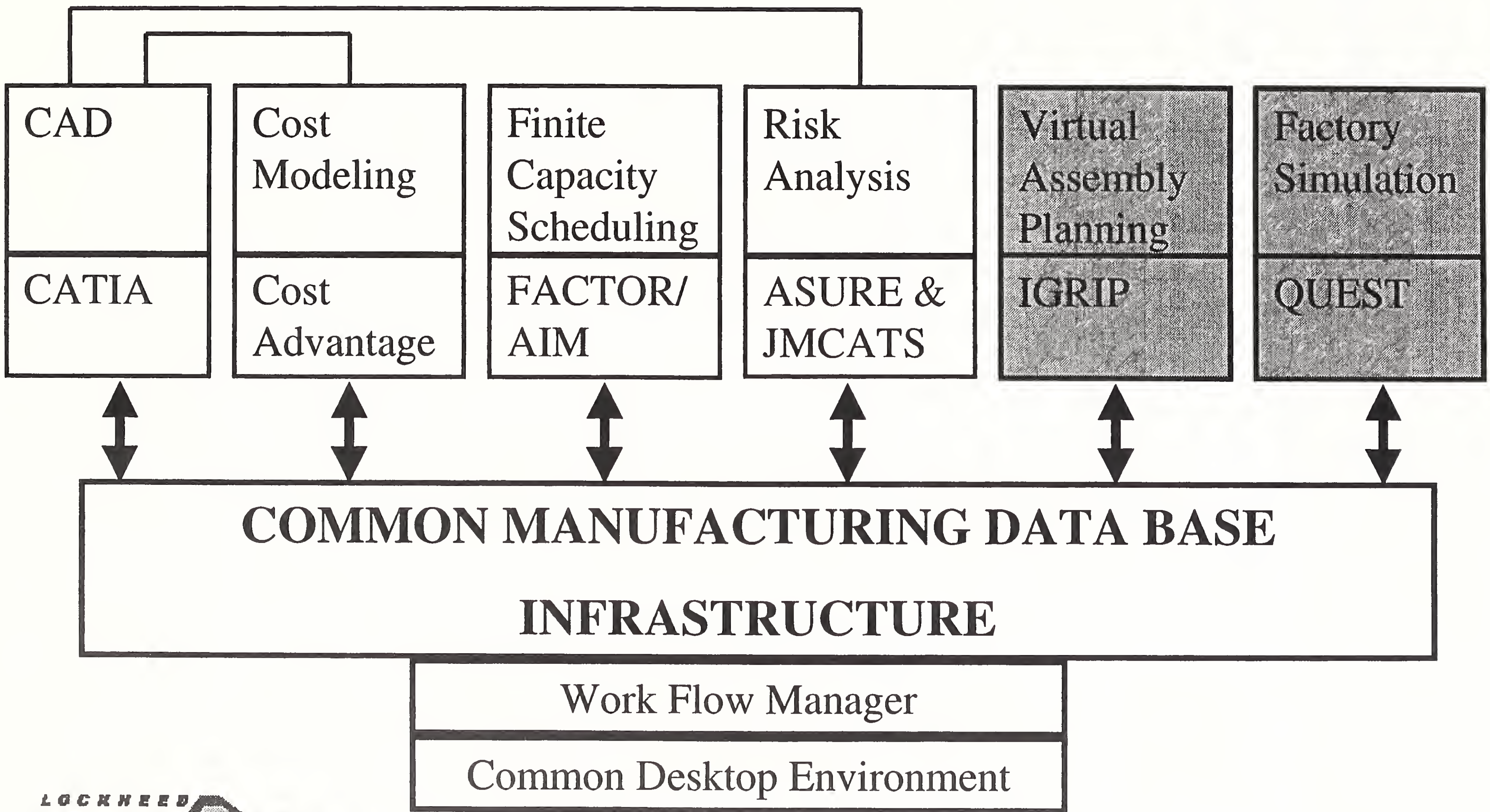
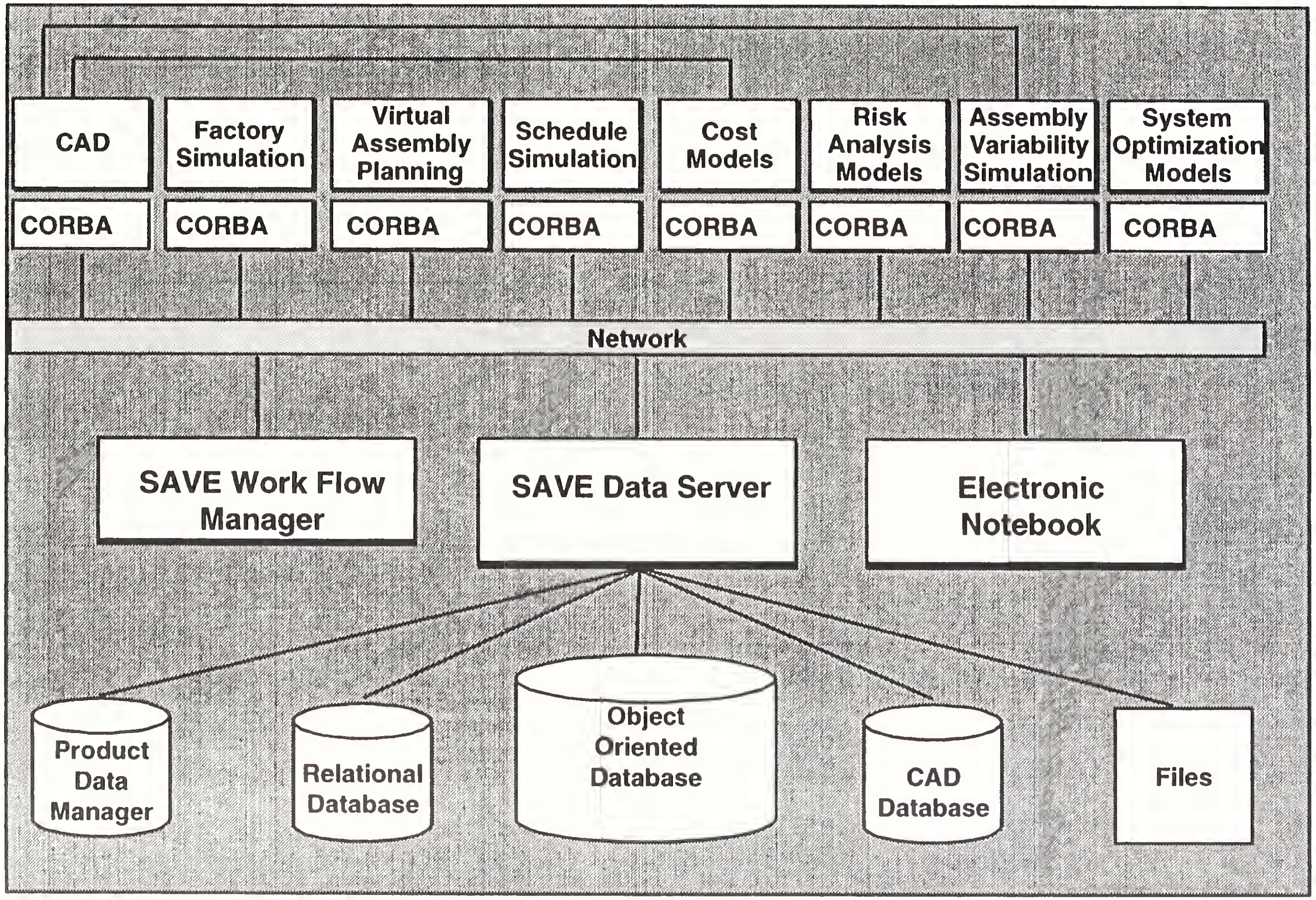
SAVE - Program Approach



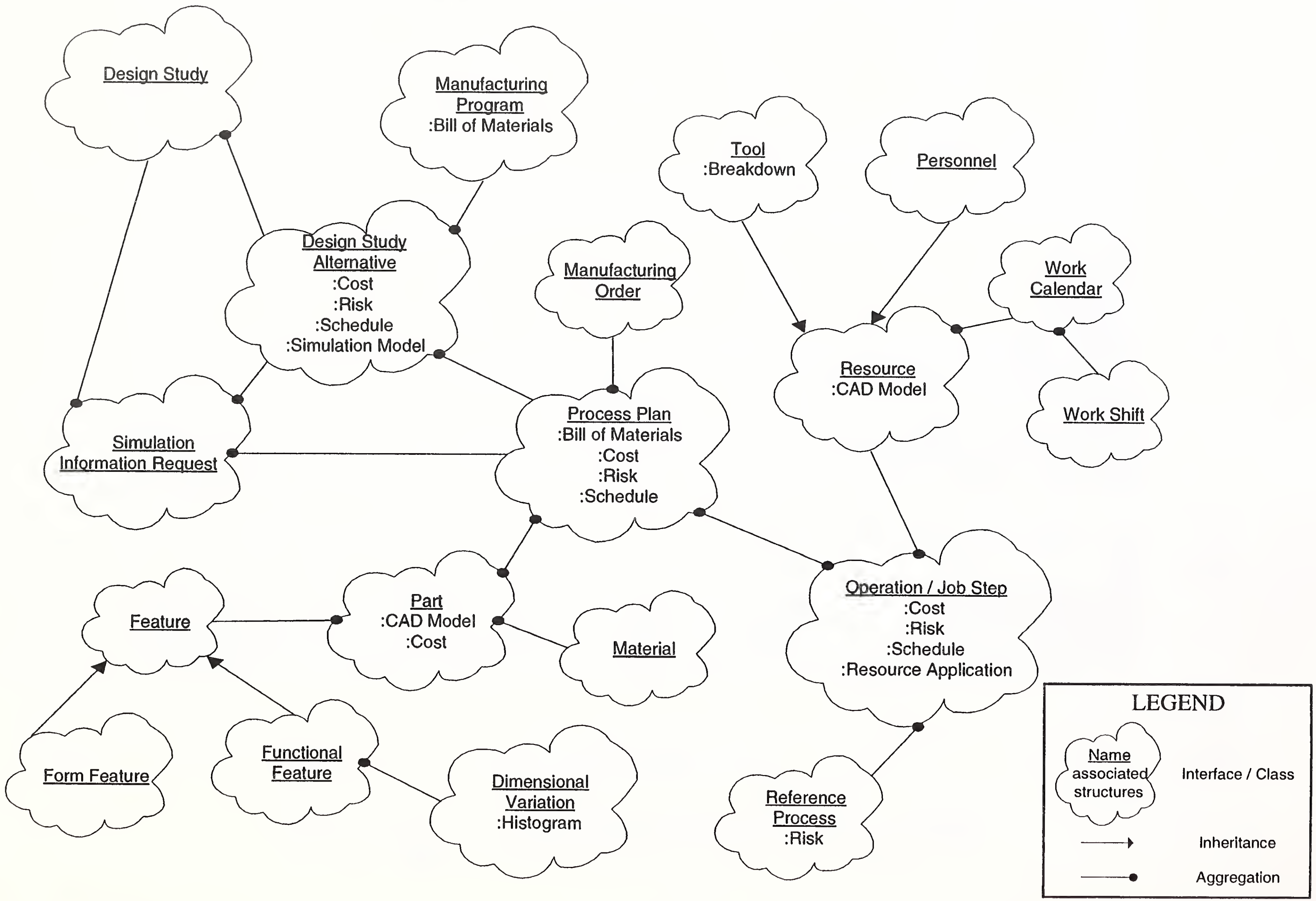
Examples of SAVE Common Data

	CAD	Factory Simulation	Assembly Planning	Schedule Simulation	Risk Analysis	Cost Analysis	Variation Analysis	Enterprise Optimization
Process Plan / Work Inst		●	●	●	●	●	●	●
Geometric Models / Defn	●		●		●	●	●	
Task Durations		●	●			●		
Resource Estimates		●		●				●
Rates and Factors		●	●	●	●	●		
Process Rates		●	●					
Factory Layout / Definition	●	●		●				
Manufacturing Rules				●		●		●
Timelines				●				●
Feature Definitions	●					●	●	
Cost					●	●		
Tolerance Limits					●		●	●
Risk		●			●		●	●

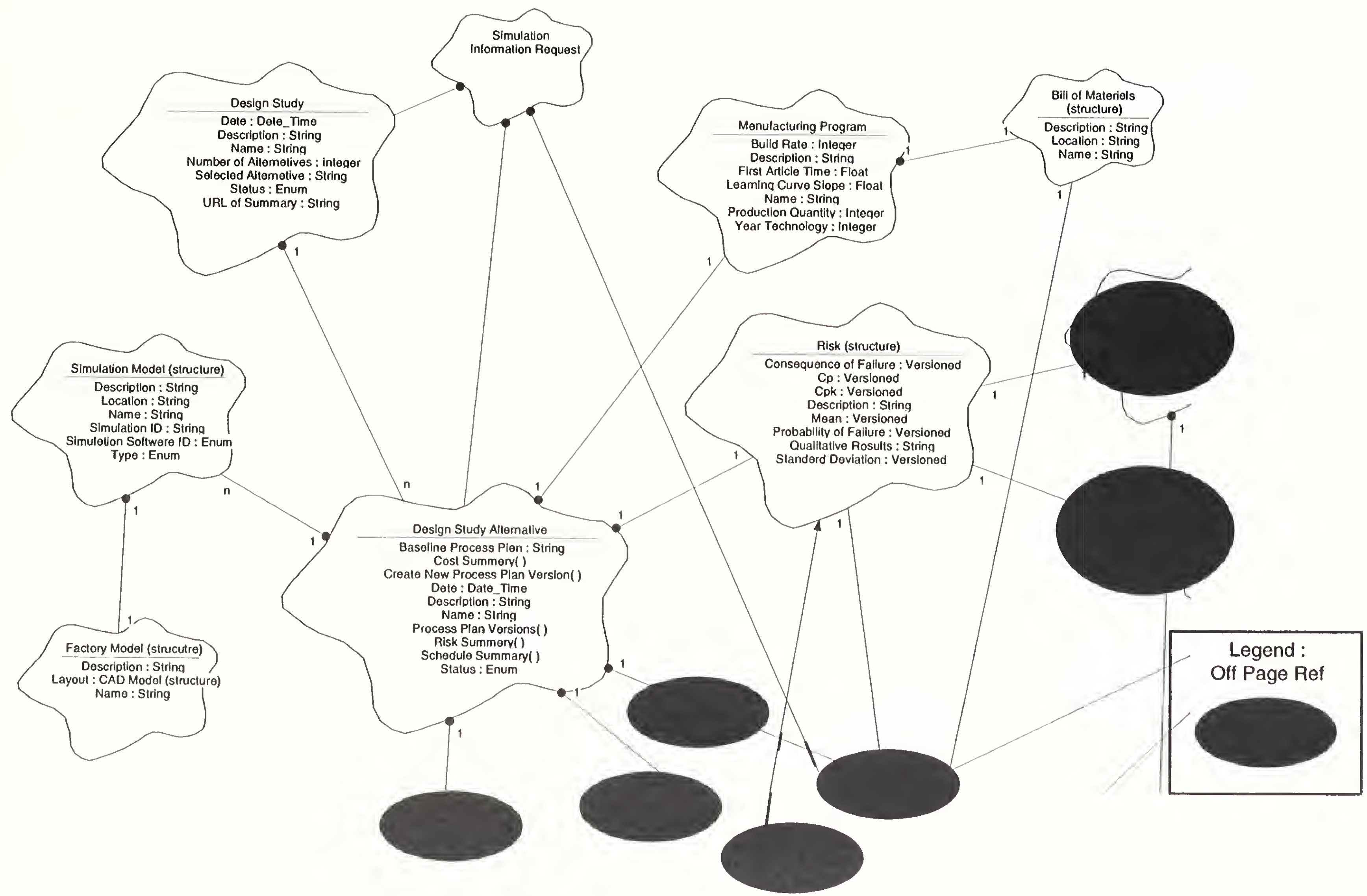
SAVE - Approach to Tool Integration



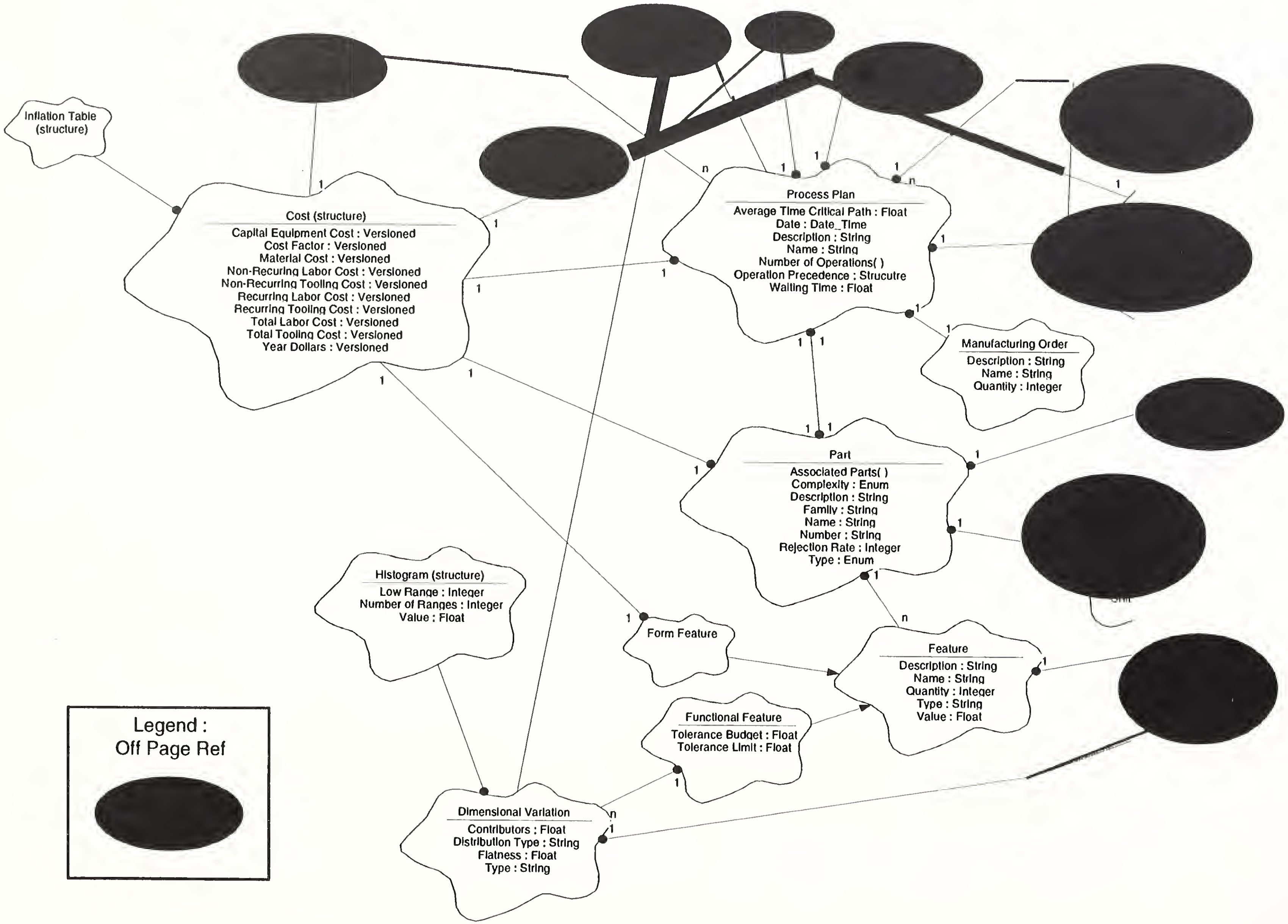
SAVE -Top Level Data Model



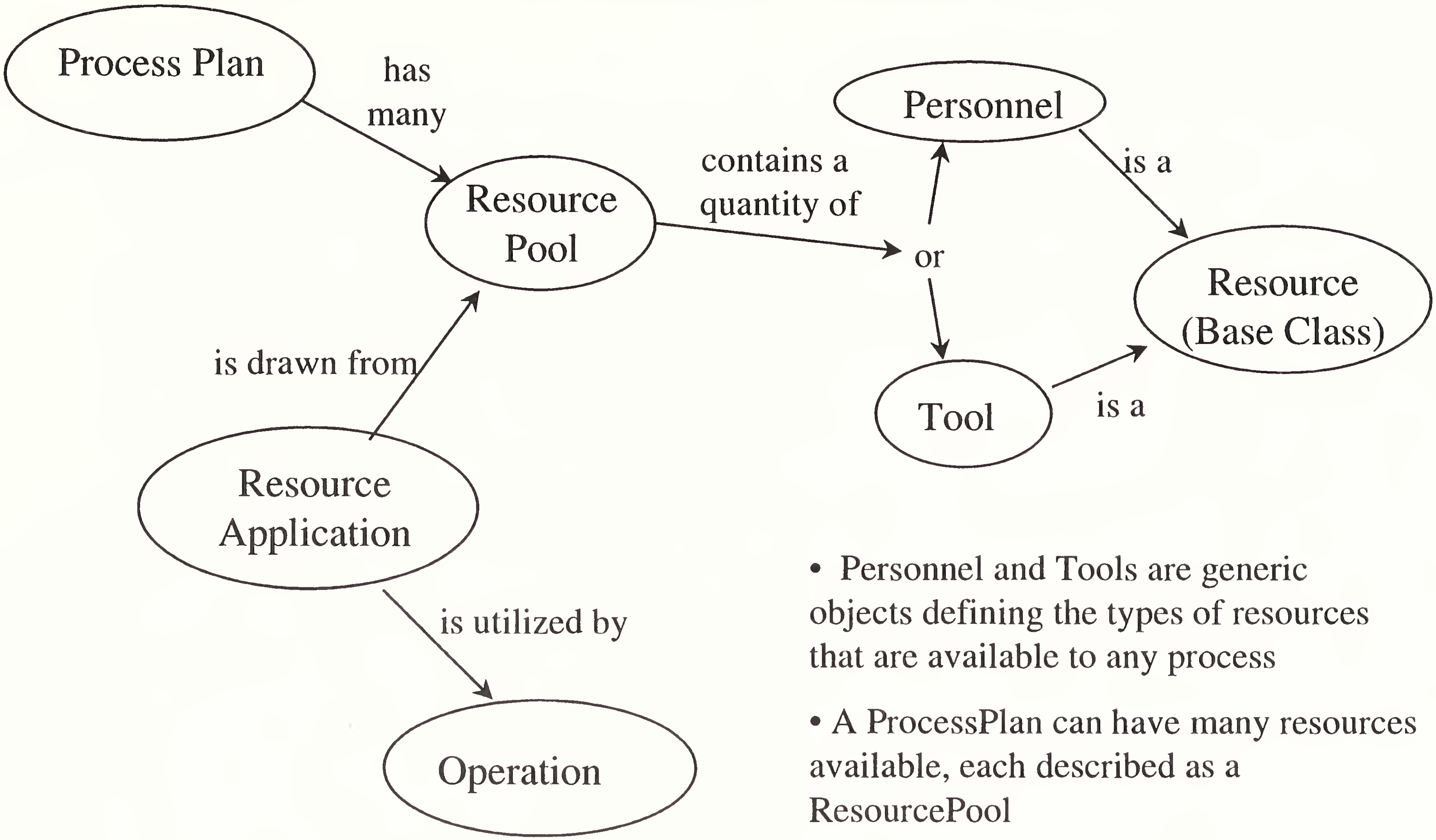
SAVE - Detailed Data Model



SAVE - Detailed Data Model



SAVE - Detailed Data Model



- Personnel and Tools are generic objects defining the types of resources that are available to any process
- A ProcessPlan can have many resources available, each described as a ResourcePool
- Any Operation in a ProcessPlan can draw from one or more ResourcePools associated with its ProcessPlan - Each use is a ResourceApplication

SAVE - IDL

Interface msmOperation
IDL source   Global index
interface msmOperation :
msmNamedObject

- Characteristics
- Cost
- CriticalPath
- Features
- Id
- Part
- PersonResApplic
- Precedents
- ProcPlan
- Quantity

QueueAvgCapacity

- QueueDurationHr
- QueueTotalCapacity
- RefProcess
- Risk
- Runtime
- Schedule
- SetupDescription
- SetupDurationHr
- ToolResApplic

Process Specification Language: A Justification

Kurt Freimuth, Agiltech Inc.

Mr. Freimuth is President of AgilTech, Inc., a company that sells software solutions for manufacturing and design engineers, including MetCAPP and CostDesigner.

Mr. Freimuth has over twenty years of computer industry experience primarily relating to manufacturing and engineering applications. He has designed, developed and implemented logistics applications. He has sold and implemented a wide range of CAD/CAM/CAE and CAPP systems. (CAE and CAPP are the acronyms for Computer-Aided Engineering and Computer-Aided Process Planning, respectively.) Mr. Freimuth is recognized internationally as a speaker on manufacturing topics and serves on a variety of academic and industry advisory boards.

Mr. Freimuth has significant experience in the commercialization of manufacturing and engineering software products. He has developed market plans, selected target markets, determined pricing and distribution policies, developed both direct and reseller channels, and designed packaging and implementation services.

AGILTECH™

Process Specification Language: A Justification

NIST

Process Information Technology Workshop

March 12, 1998

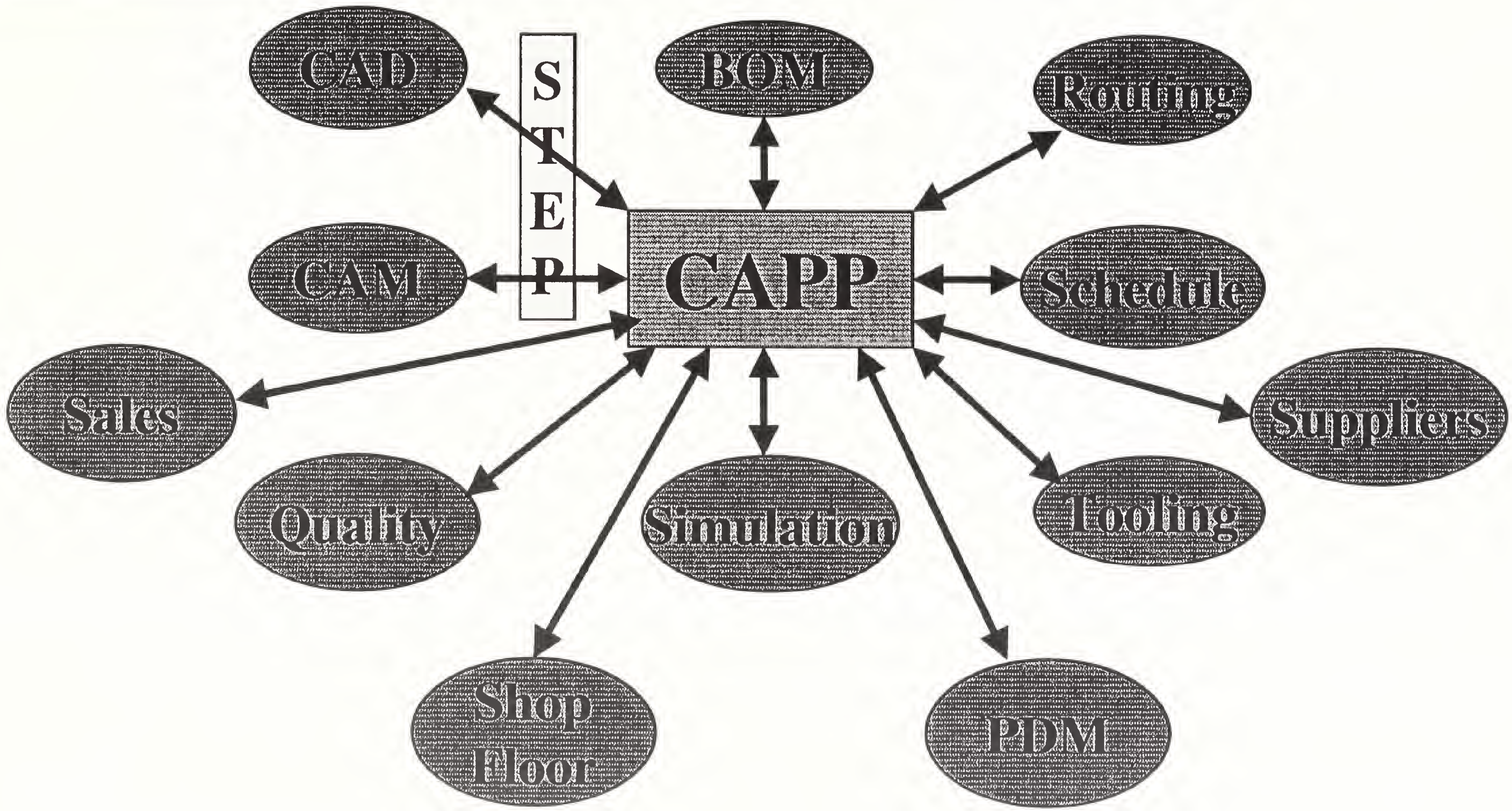
AGILTECH

PSL and Process Planning

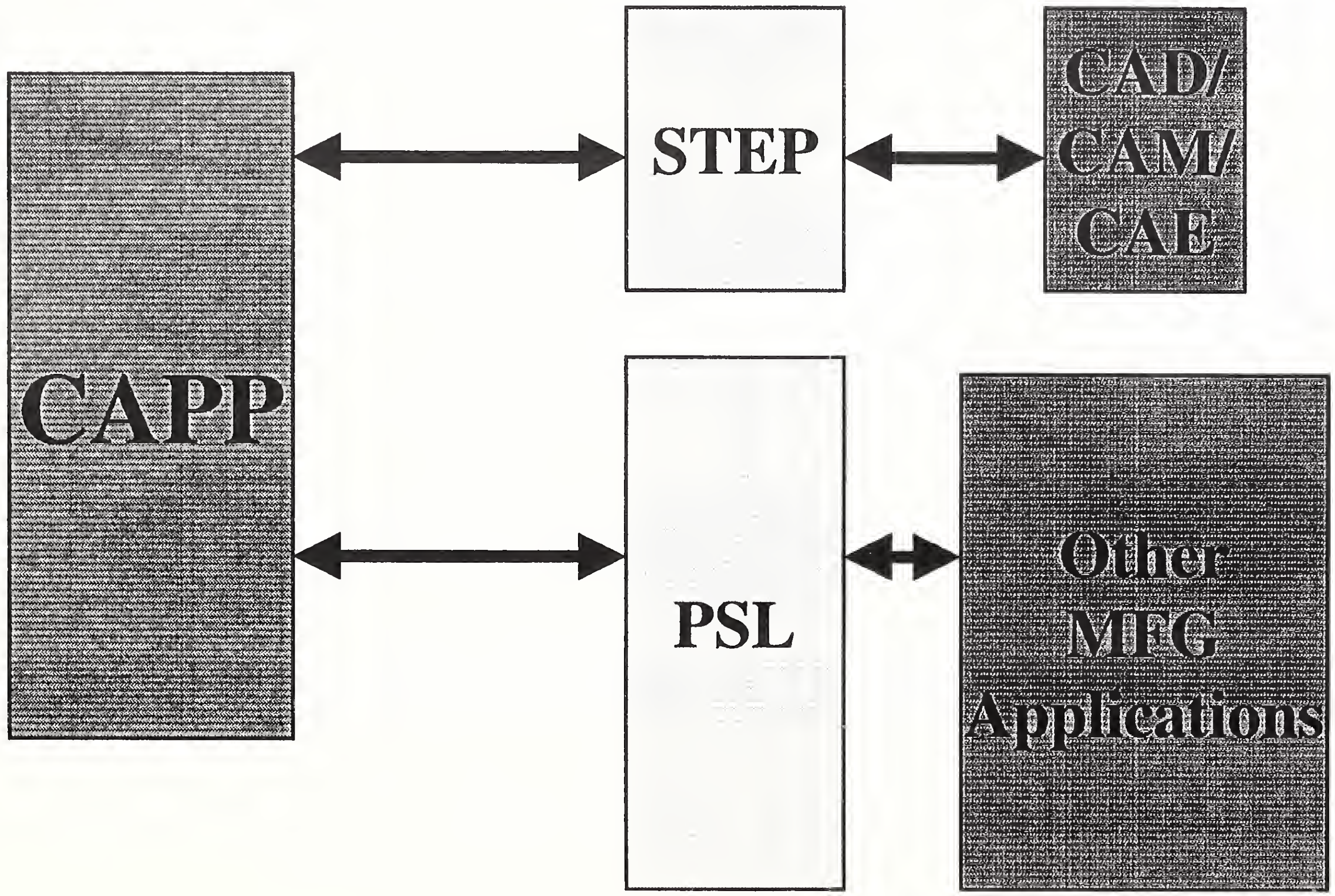
- AgilTech Designs, Develops and Sells a CAPP Application - MetCAPP
- CAPP Uses Include:
  - Routing Design & Engineering
  - Cost Estimating
  - Process Documentation

AGILTECH

Process Planning Current Implementations



Process Planning PSL Implementations



AGILTECH

Economics of PSL

- Current Method of Point-to-Point Interfaces
  - Average 6 per installation @$6,000 each
  - Maintenance at 25% per year
- Total Cost of Acquisition/Ownership
- PSL Eliminates Most Point-to-Point Interfaces
- Lower Acquisition and Maintenance Costs

AGILTECH

Economics of PSL

- Opportunity Costs
  - A change in any application which generates benefits to the user can be delayed by the need to rewrite the point-to-point interface between the new version and all other applications.

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Why Does AgilTech Support PSL?

- Lower Costs for Our Customers
- Lower Support Costs for AgilTech
- Faster Implementations for Customers
- Shorter Payback Periods for Customers
- Greater Customer Satisfaction

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PSL = $$

For Manufacturers

Process Information and EXPRESS

John Valois, STEPTools, Inc.

John D. Valois is Product Manager and lead developer for EXPRESS tools at STEP Tools, Inc., and is a member of the teams developing the second edition of EXPRESS and the first edition of EXPRESS-X within Working Group 11 of ISO TC184/SC4. He has a Ph.D. in Computer Science from Rensselaer Polytechnic Institute in Troy, NY.

Process Information and EXPRESS

John D. Valois
valois@steptools.com

STEP Tools, Inc.
Rensselaer Technology Park
Troy, New York 12180

(518) 276-2848   (518) 276-8471 fax
info@steptools.com   http://www.steptools.com

Overview

- EXPRESS and STEP
  - Relationship to the discrete process industry
- Current capabilities
  - Data exchange
  - What tools are available?
- Future capabilities
  - Mapping languages
  - The 2nd edition
  - What will the tools look like?

What is EXPRESS?

EXPRESS is the data modeling language of STEP

- STandard for Exchange of Product data (ISO 10303)

- Scope includes:
  - Data exchange, sharing and integration, archiving

- Covers over 30 engineering disciplines
  - Form features for NC machining
  - Process plans for NC machining
  - Design and manufacturing of composites
  - PCA manufacturing planing

What is EXPRESS?

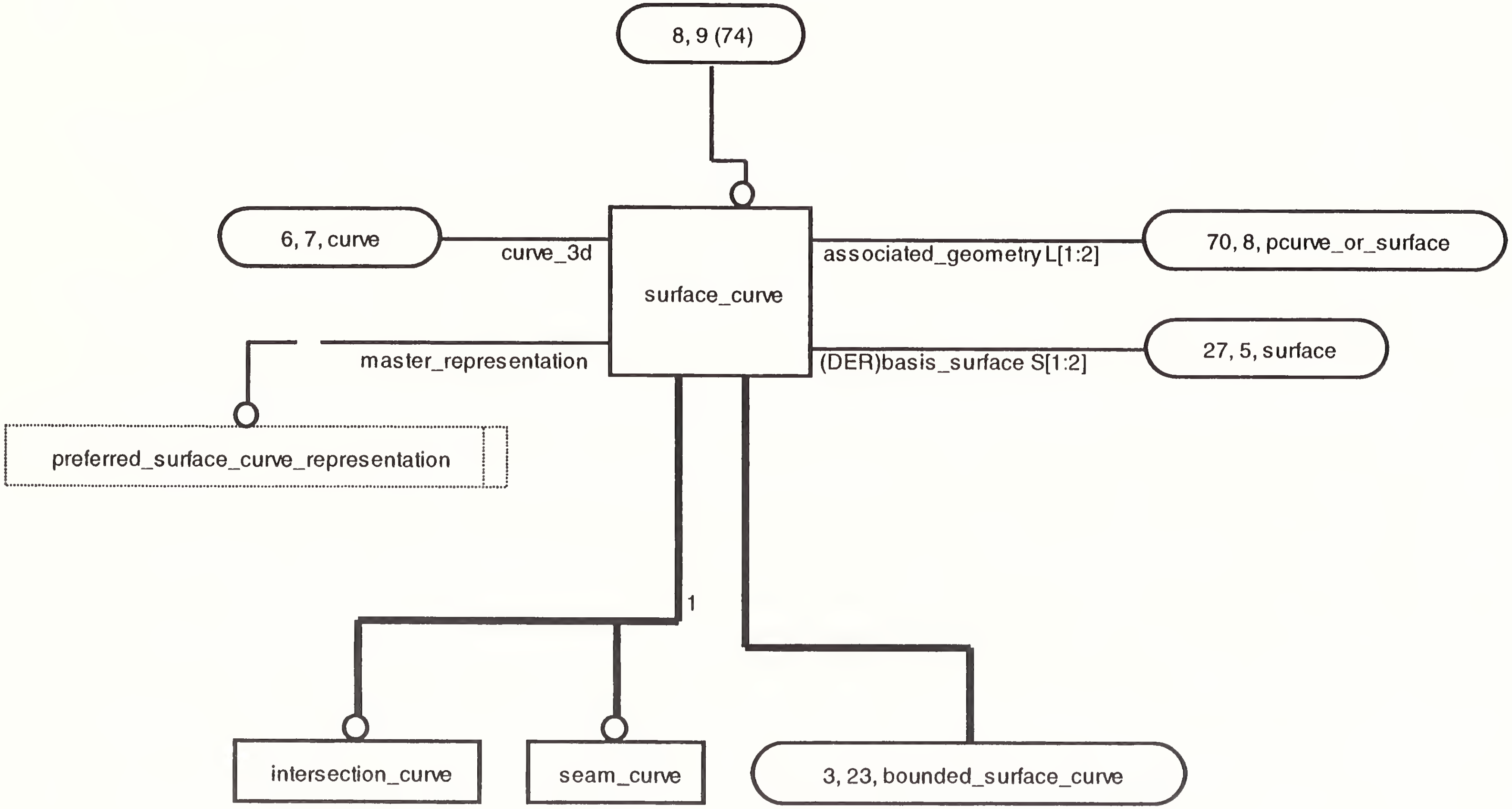
- Text based, with a graphical form (EXPRESS-G)

- Formal specification of:
  - Physical structure
  - Semantics
  - Constraints

- Coupled with implementation methods for:
  - Clear text encoding
  - Generic programming API
  - C++, IDL, Java, etc. language bindings

```
ENTITY surface_curve

SUPERTYPE OF (ONEOF(intersection_curve,
                    seam_curve)
             ANDOR bounded_surface_curve)
SUBTYPE OF (curve);

 curve_3d : curve;

 associated_geometry
  : LIST[1:2] OF pcurve_or_surface;

 master_representation
  : preferred_surface_curve_representation;
```

```
DERIVE

  basis_surface : SET[1:2] OF surface
        := get_basis_surface(SELF);

WHERE

  WR1: curve_3d.dim = 3;

  WR2: NOT('GEOMETRY_SCHEMA.PCURVE' IN
           TYPEOF(curve_3d));

END_ENTITY;
```


8, 9 (74)
6, 7, curve
curve_3d
surface_curve
associated_geometry L[1:2]
70, 8, pcurve_or_surface
master_representation
(DER)basis_surface S[1:2]
27, 5, surface
preferred_surface_curve_representation
1
intersection_curve
seam_curve
3, 23, bounded_surface_curve

1. Construct the model (or use a standard)

   - EXPRESS-G viewer/editor
   - EXPRESS compiler

2. Implement pre- and post-processors

   - Code generators, core libraries
   - Standard file format I/O libraries
   - API libraries/language binding implementations

3. Verify conformance

   - Constraint validation tools
   - Data editors

EXPRESS-X is the mapping language of EXPRESS

- Currently under development

- Provides for formal specification of:
  - Relationship between different data definitions
  - Legacy data migration path
  - Schema evolution
  - Views of data
  - Data integration and interoperability

- Several prototype implementations available (all commercial)

- What can they do?

  - Translator implementation
    - Driven directly from formal specification

  - View materialization
    - Finding "business objects"

Adds dynamic modeling capabilities

- Model states

  and

- Transitions between states, plus
- Constraints on state transitions

Now possible to model discrete processes

- How can industry benefit?

Possibilities:

- Control the process from the specification
  - Describe "what", not "how"
  - Search for optimal process

- Verifying the process from the specification
  - After the fact, or
  - Online monitoring

- Archiving how a process was performed
- Documenting how a process changes over time

Conclusion

- EXPRESS and STEP now provide a standard framework for process information exchange

- New parts of the standard will soon enable:
  - Data sharing and integration, translation
  - Formal process description

- Tools will help to leverage these standards into working systems

What problems does the industry need solved?

Tools for inventing organizations: Toward a handbook of organizational processes

Mark Klein, MIT

Dr. Mark Klein is a Research Associate in the MIT Center for Coordination Science, where he manages the Process Handbook project and conducts research in coordination science. He has worked on advanced research and development in both industrial (Boeing, Hitachi) and academic (University of Illinois, Pennsylvania State University, MIT) settings. His professional activities include invited talks on three continents, chairing several international workshops, guest editing special journal issues on collaborative design as well as serving on numerous editorial boards and conference program committees. Mark has published over 40 papers.

Tools for inventing organizations:

Toward a handbook of organizational processes

Primary collaborators

- Tom Malone
- Kevin Crowston
- Jintae Lee
- Brian Pentland
- Chris Dellarocas
- George Wyner

- Charley Osborn
- Fred Luconi
- John Quimby
- Avi Bernstein
- Marc Gerstein
- Mark Klein
- ...

Sponsors

- Consulting firms (A.T. Kearney, Andersen ...)
- Large manufacturers (Siemens, Fuji Xerox ...)
- Government agencies (DARPA, NSF, DLA)

Outline

- Goals
- Key Ideas & Examples
  - Specialization (with inheritance)
  - Dependencies
- Status

Question

- How else could we do this?

Imagine a black box with ...

- collections of alternative process descriptions
- at various levels of specialization
- with case examples, "tips for success", advantages, and disadvantages
- links to "distant analogies"
- and on-line discussions for each process type

Process Handbook Uses

- (Re)designing organizational processes
  - especially those enabled by IT
- Sharing process knowledge: best practices, new ideas, experience ...
  - teaching new members about an organization
  - “yahoo for process knowledge”
  - “virtual university”
- Automatically generating software
  - e.g., simulation, workflow automation

How to represent processes?

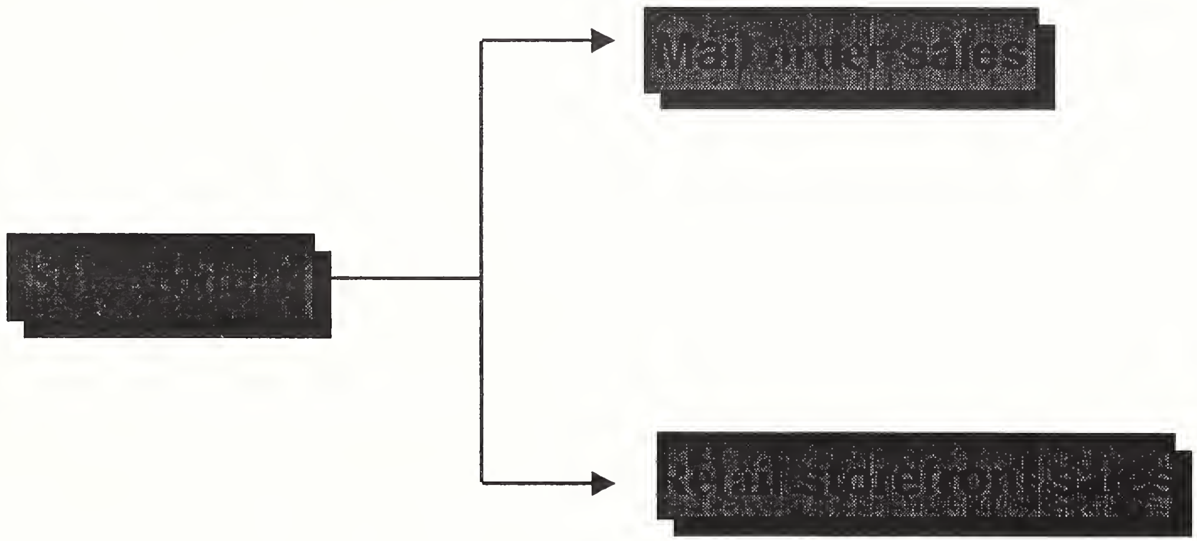
- Flow charts
- Data flow diagrams
- State transition diagrams
- Petri nets
- ...

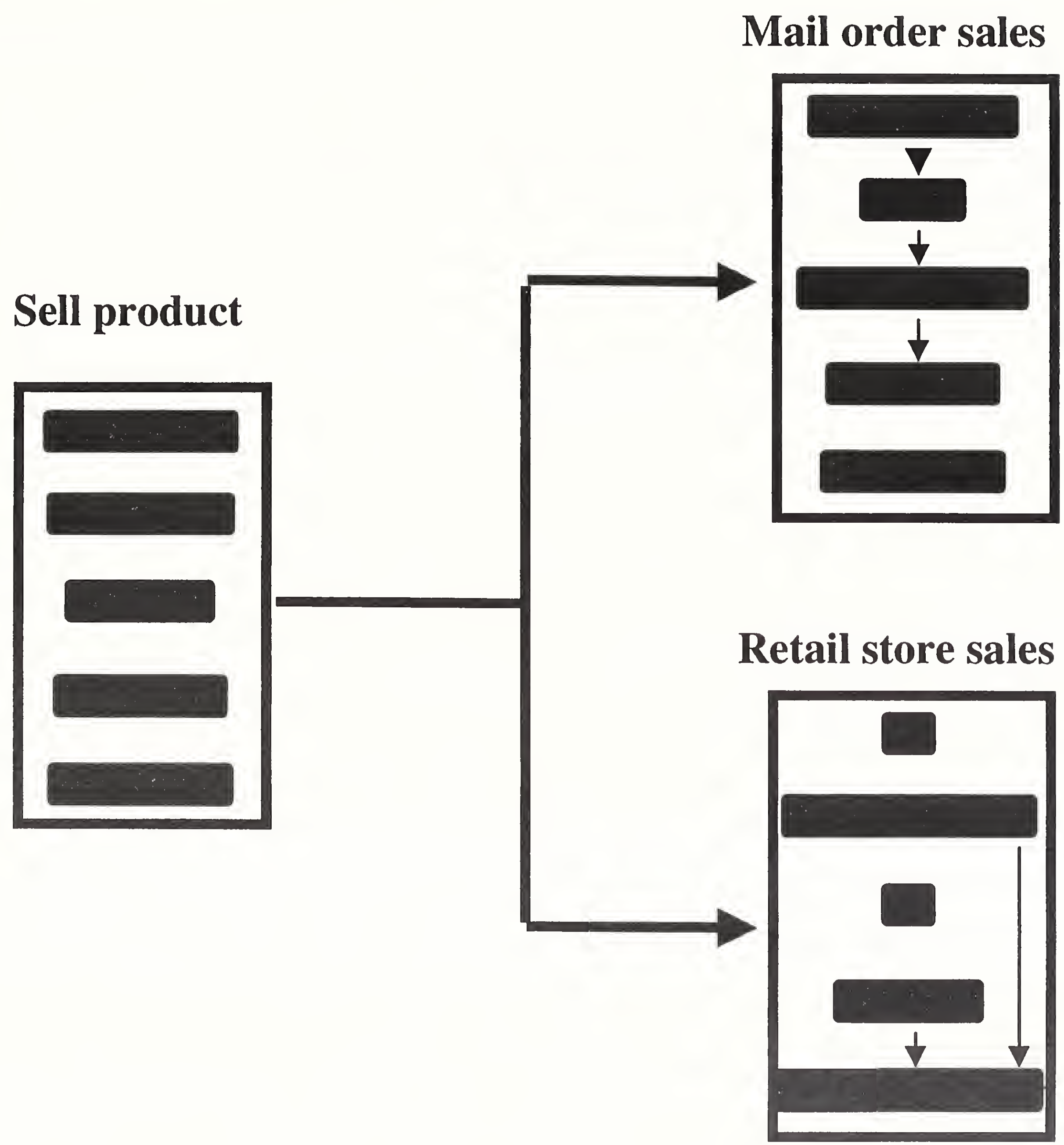
Baseline: A looseleaf binder of flowcharts

Key sources of leverage

- Specialization of processes
  - with inheritance
- Dependencies
  - opportunities for coordination

Specialization of processes




Sell product
Mail order sales
Retail store sales

Tradeoff Tables

Bundle Details: 'Sell how?'

File Context Bookmarks History Window

Specializations	Cost of selling	Time to sell	Quality of service	Suggested products
Sell by direct sales	High	Long	High	High margin, tailored
Sell by mail order	Low	Medium	Low	Specialty items
Sell by retail store	Medium	Medium	Medium	Low margin commodities
Sell over internet	Low	Fast	Low-improving	Commodities, Specialty items

Direct sales provides the customer with individual attention by a person. This provides the best customer satisfaction, but is a high cost method. It also takes a long period of time and is limited by the amount of sales staff.

Mail order is inexpensive, but is not tailored to the customer. It is average for amount of

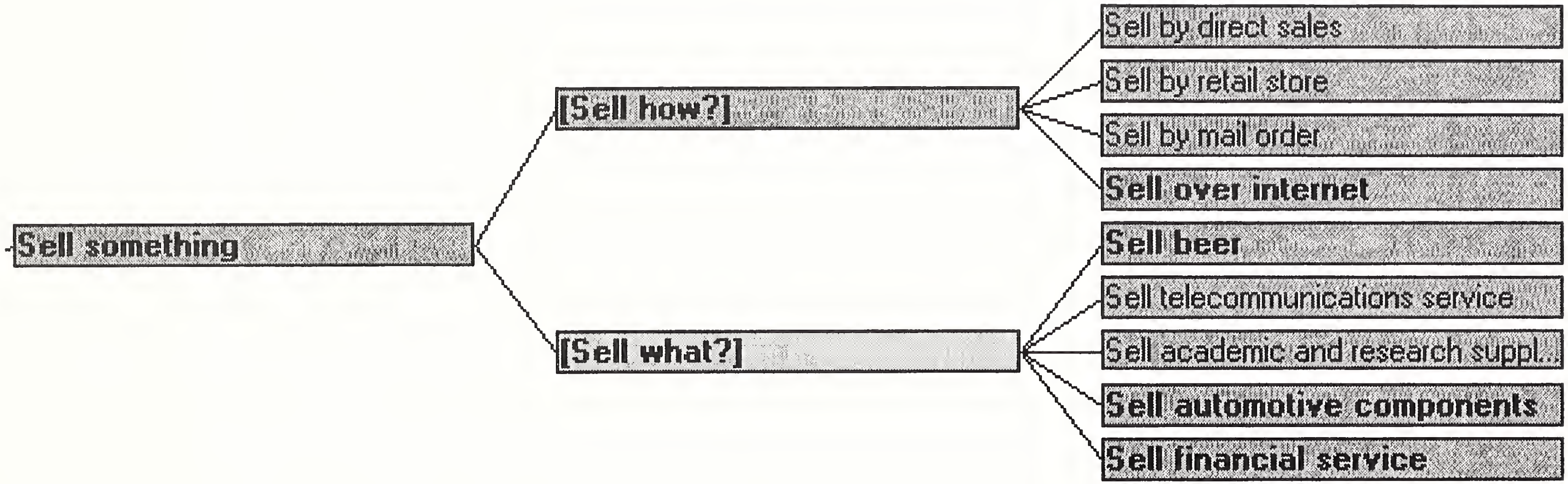
New Attribute | Rename Attribute | Delete Attribute

Trade Offs | Regular | Display | Attachment

Finding Relevant Knowledge

- search by semantics, not just keywords
  - regardless of domain
- bundles constrain search
- relevant content is nearby
- linked to distant analogies (cousins ...)

Interesting Siblings



Distant Analogies

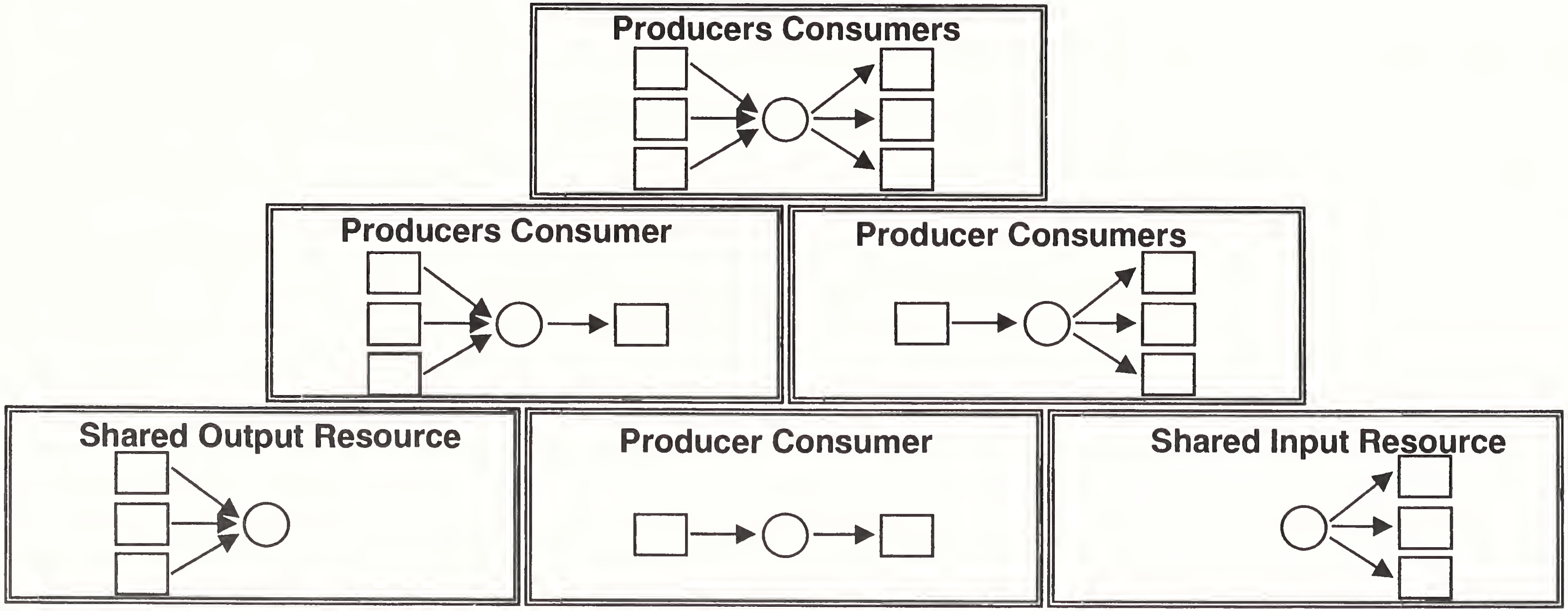
- How to hire new employees?
  - analogies from “buy” (grandparent)
    - » on-line parts database (Acer)
    - » company-wide parts standards (Motorola)
  - analogies from “sell” (uncle)
    - » test drive before buying (BMW)

What is coordination?

Coordination -

managing (key) dependencies among (core) activities

Taxonomy of dependencies



Coordination Mechanisms

Dependency	*Examples of coordination processes for managing dependency*
Shared resources	"First come/first serve", priority order, budgets, managerial decision, market-like bidding
Task assignments	(same as for "Shared resources")
Producer / consumer relationships	
Prerequisite constraints	Notification, sequencing, tracking
Transfer	Inventory management (e.g., "Just In Time", "Economic Order Quantity")
Usability	Standardization, ask users, participatory design
Design for manufacturability	Concurrent engineering
Simultaneity constraints	Scheduling, synchronization
Task / subtask	Goal selection, task decomposition

Re-Designing Processes

- What is the deep structure of this process?
  - What are the <u>core</u> activities?
  - What are the <u>key</u> dependencies?
- What surface structures are possible?
  - How can the activities be specialized?
  - How can we coordinate dependencies?
  - Get alternatives via close and distant analogies

Example: Hiring

- Hiring requisitions to recruiters
  - currently: “make to order”
  - options: “make to forecast” (link to business plan, options market ...)

Current Status

- Software
  - Windows and Web based Prototypes
  - Process Interchange Format (PIF v1.1)
  - Object-oriented API
- Content
  - more than 4500 Process descriptions
  - from logistics, health care, agile manufacturing ...
  - theory, generic & case-study based
- Theory & Methodology
  - Taxonomy of dependencies
  - Design and editorial methodologies

Future Plans

- theory (representation & structure)
- methodology
- software
- content

Theory

- extend taxonomy (ports, dependencies ...)
- control knowledge
- process rationale
- adaptive processes

Methodology

- process design
  - esp. design space pruning
- “broadening the circle”
  - on-line communities
  - editorial processes
- pedagogy

Software

- process design assistants (“recombinator”)
- PH_Web “lite” & “heavy”
- process query language
- object-based data layer with access control

Content

- agile manufacturing
- logistics
- 3rd party repositories (Navy, Arthur Andersen, Lean Aircraft Initiative ...)
- ...

Conclusions

- The Process Handbook: evolving technology to support:
  - business process re-design
  - innovation
  - learning about organizations
  - software

Process Information Technology Overview

Perakath Benjamin, KBSI

As KBSI's Vice President for R&D, Dr. Perakath Benjamin provides technical leadership and direction to the organization’s R&D initiatives. Dr. Benjamin is the Principle Investigator for the DARPA Virtual Enterprise Engineering Project that led to the development of advanced process management tools and a preliminary theory of process knowledge representation. The process knowledge representation work is continuing through the NIST PSL effort. Dr. Benjamin was one of the principal developers of the IDEF3 process modeling method and the IDEF5 ontology modeling method, emerging Department of Defense (DoD) standards for process and ontology modeling. Dr. Benjamin has been the PI on a number of R&D projects in knowledge-based simulation, planning and scheduling systems, AI applications manufacturing systems, activity based costing, process management methods and tools, and ontology management technology.

Process Information Technology Overview

Perakath Benjamin
Knowledge Based Systems, Inc.
pbenjamin@kbsi.com
www.kbsi.com

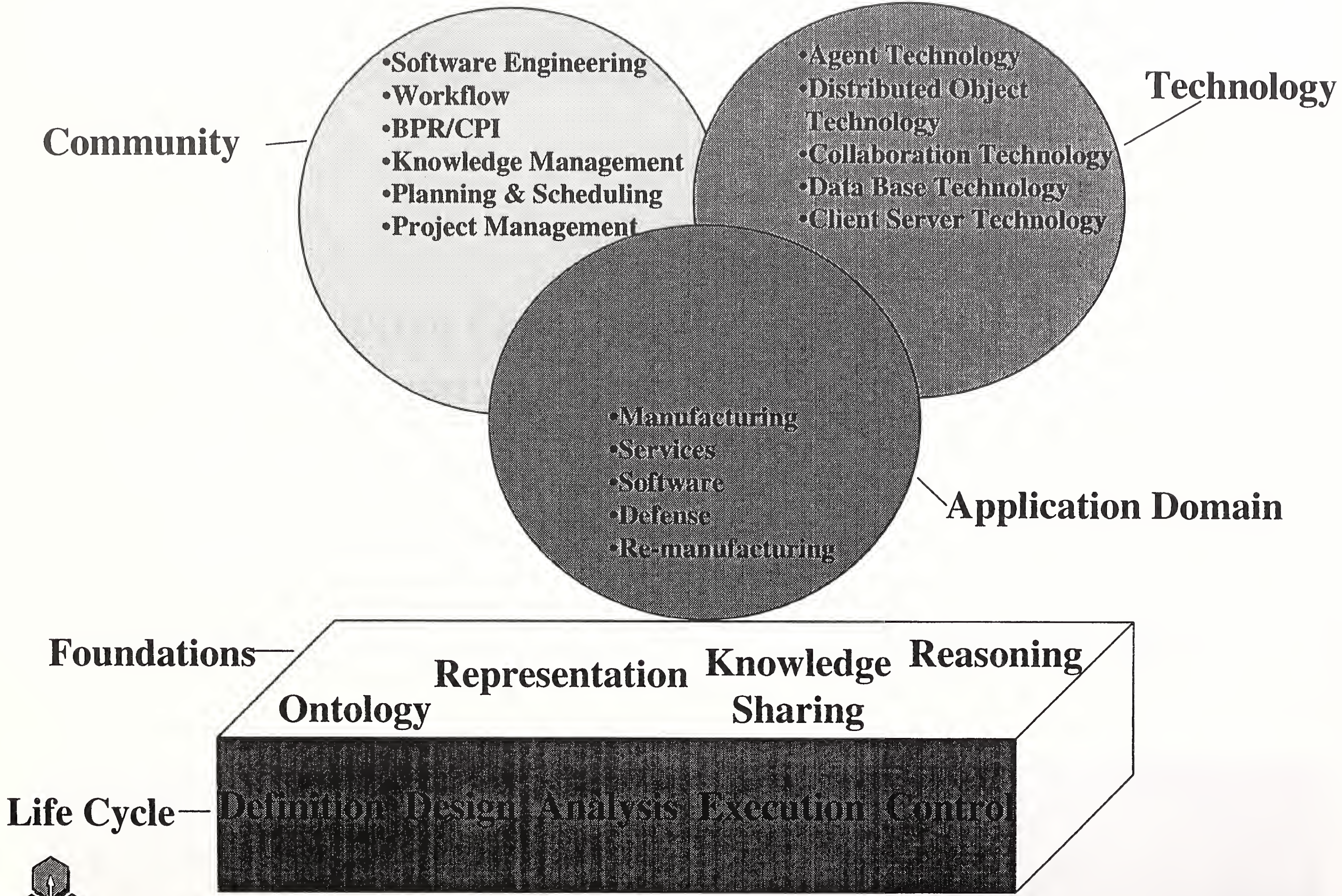
Outline

- Definitions
- Perspectives
- Significance
- Process life cycle
- Technical challenges and gaps

What is Process Information Technology?

- Information technology that addresses the needs of process management
- Process management
  - Conceptualization, design, analysis, execution, and control of processes

Process Perspectives



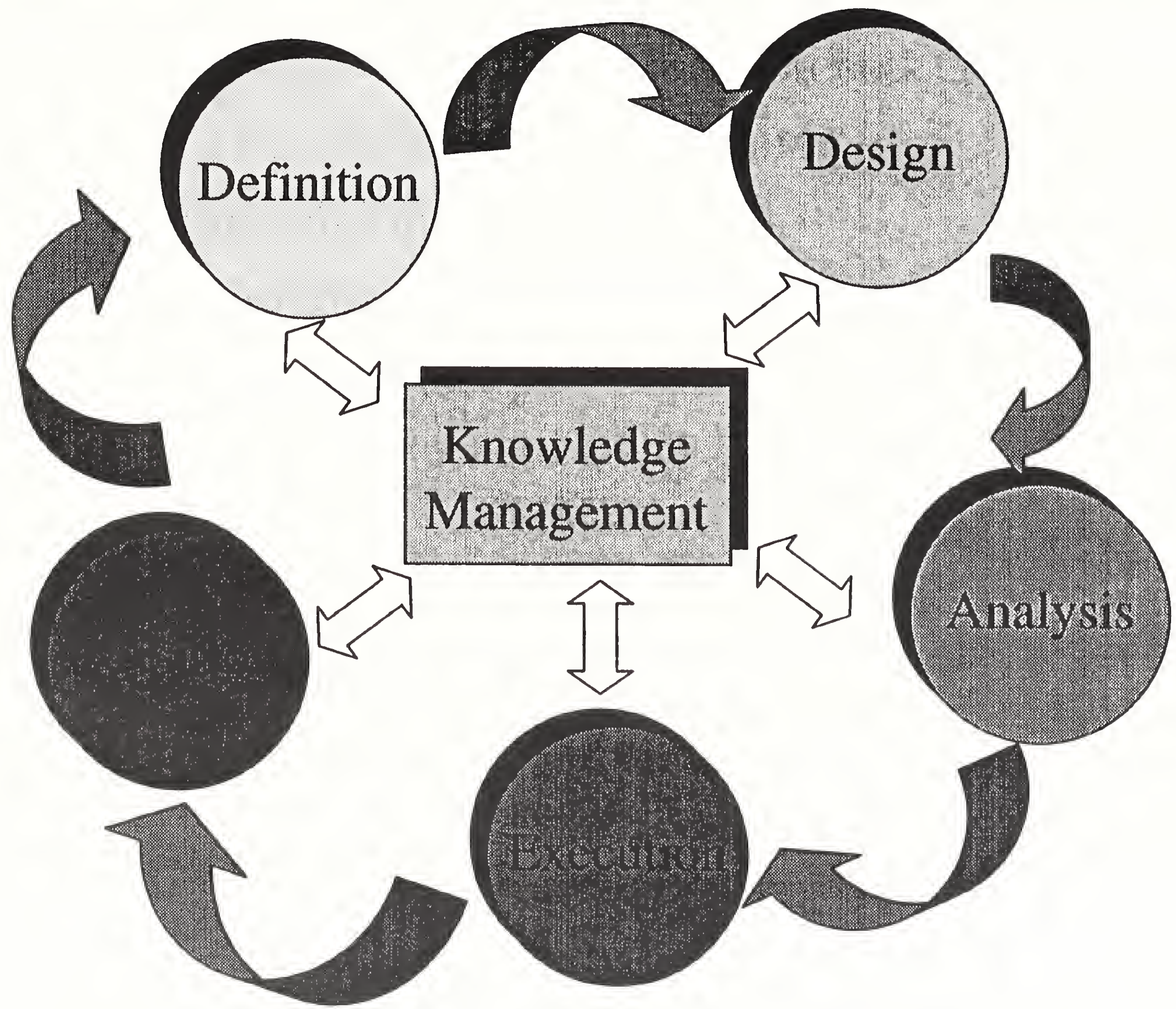
Significance of Process Information Technology

- Processes are pervasive
  - Influence every organization
  - Are critical to many communities
    - Software Engineering, workflow, planning and scheduling, BPR/CPI, knowledge management
- Process technology has largely been ignored by the scientific community
  - Focus has been on *product* at the expense of *process*
- Significant pay-off
  - Critical for managing change in an increasingly unpredictable environment
    - Important requirement for *agile* enterprises

Why Process Management is Hard

- Processes are intrinsically abstract
- Representational requirements are complex
- Analysis mechanisms are complex
- Inadequate foundations
  - Ontologies, representation, sharing, reasoning
- Technology has lagged industry needs
  - Inadequate scientific effort focused on process
  - Progress has been ad hoc
    - Technology stovepipes
    - Lack of synergy

Process Technology - A Life Cycle Perspective



Process Definition

- Establishment of process requirements
- Definition of process intent
    - Objectives and scope
    - Performance metrics
- Functional analysis
    - Definition and evaluation of what a system or organization must do
        - Decomposition of functions
        - Assignment of high level process steps to decomposed functions
- Process requirements drive subsequent phases of the process life cycle

Process Design

- Development of an executable specification of a process
- Design Strategies
  - Variant process design vs. generative process design
- Multiple perspectives
  - Plan design, schedule design, process planning, workflow design, agent/software behavior design
- Process design is more art than science
  - Current practice: heuristic and often ad-hoc
  - Technology has lagged industry demand
- Previous scientific efforts have focused on product design rather than process design

Process Analysis

- Evaluation of process performance relative to process intent
- Levels of analysis
  - Quantitative vs. qualitative vs. immersive
  - Stochastic vs. deterministic
- Multiple perspectives
  - Plan analysis, manufacturing process analysis, schedule analysis, workflow analysis, agent/software behavior analysis
- Multiple techniques and tools
  - Simulation, statistical methods, scheduling methods, cost modeling techniques, qualitative methods, immersive methods (VR-based)

Process Execution

- Enactment of the process in an operational environment
- Enactment strategy depends on nature of the process
  - Human, automated, mixed-initiative
- Multiple perspectives
  - Workflow, MES, mission critical systems, agent systems
- Rapid growth area
  - Catalyzed by the information revolution
- Need for more synergy between technology areas

Process Control

- Process execution monitoring and deviation-driven feedback
- Different levels of control
  - Reactive vs. proactive
  - Human, automated, mixed-initiative
  - Centralized vs. decentralized
- Multiple perspectives
  - Workflow control, manufacturing process control, agent-based control, plan execution control
- Need for more research and synergy

Process Foundations

- Process ontologies
  - Characterization of basic process concepts
- Process knowledge representation
  - Robust languages
  - Sound theories
- Process knowledge sharing
  - Sharing requires robust representation
  - Need for standards
    - NIST and WfMC are taking the lead
- Automated reasoning
  - Most work to date from AI and software engineering communities
- Needs more research and synergy of efforts

Technical Challenges and Gaps

- More research and harmonization of efforts needed in many areas
  - Foundations
    - Theory, ontology, representation, sharing
  - Process design
    - Principles, methods, and tools
  - Process analysis
    - Integration of mature technologies from multiple communities
  - Process execution
    - Workflow community is a major player
      - currently driven by the market, needs more disciplined research
  - Process control
    - Need to integrate results from different areas
    - Agent-based community will likely play a major role

Presentation Title: Process Specification and Interchange: A WfMC Perspective
Presenter: David Hollingsworth, WfMC

David Hollingsworth has spent in excess of 25 years in the IT industry and works for ICL, a part of the Fujitsu Group specializing in systems integration and services world wide. His career with ICL spans roles in product development, market requirements, strategic planning, systems architecture and major projects consultancy assignments. He has a technical background (networking, messaging, groupware applications and systems integration) and recent industry experience in financial card / payment based systems.

His interest in workflow systems dates from 1992 and as ICL's architect for office systems he was involved in the establishment of the Workflow Management Coalition as the industry standards body for workflow. He is currently chairman of its Technical Committee and has authored several of its reference documents. He holds an honors degree in Economics from the London School of Economics and is an ICL Distinguished Engineer.

Process Specification & Interchange: A WfMC Perspective

David Hollingsworth, ICL; Chair, WfMC TC

David Hollingsworth has spent in excess of 25 years in the information technology industry and works for ICL, a part of the Fujitsu Group specializing in systems integration and services world-wide. His career with ICL spans roles in product development, market requirements, strategic planning, systems architecture, and major projects consultancy assignments. He has a technical background (networking, messaging, groupware applications, and systems integration) and recent industry experience in financial card / payment-based systems.

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WfMC

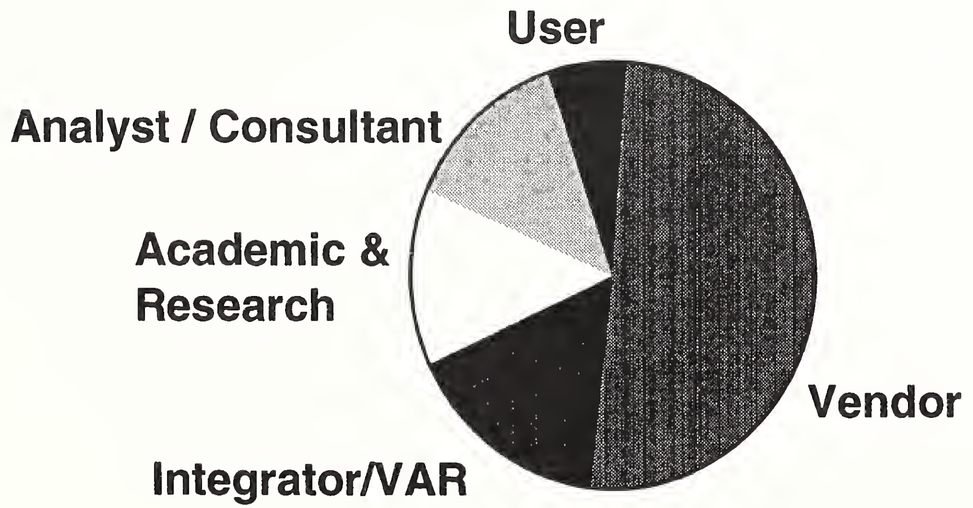
Process Specification & Interchange

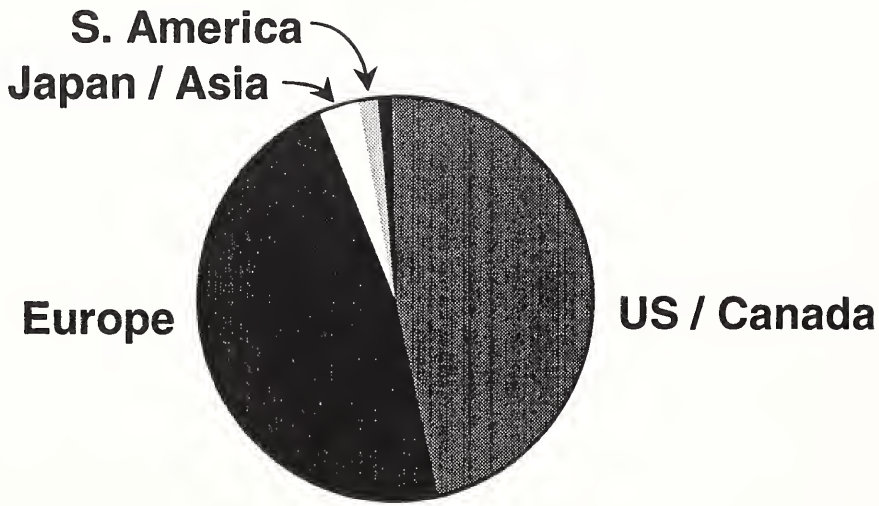
A WfMC Perspective

David Hollingsworth, ICL
Chair, WfMC TC

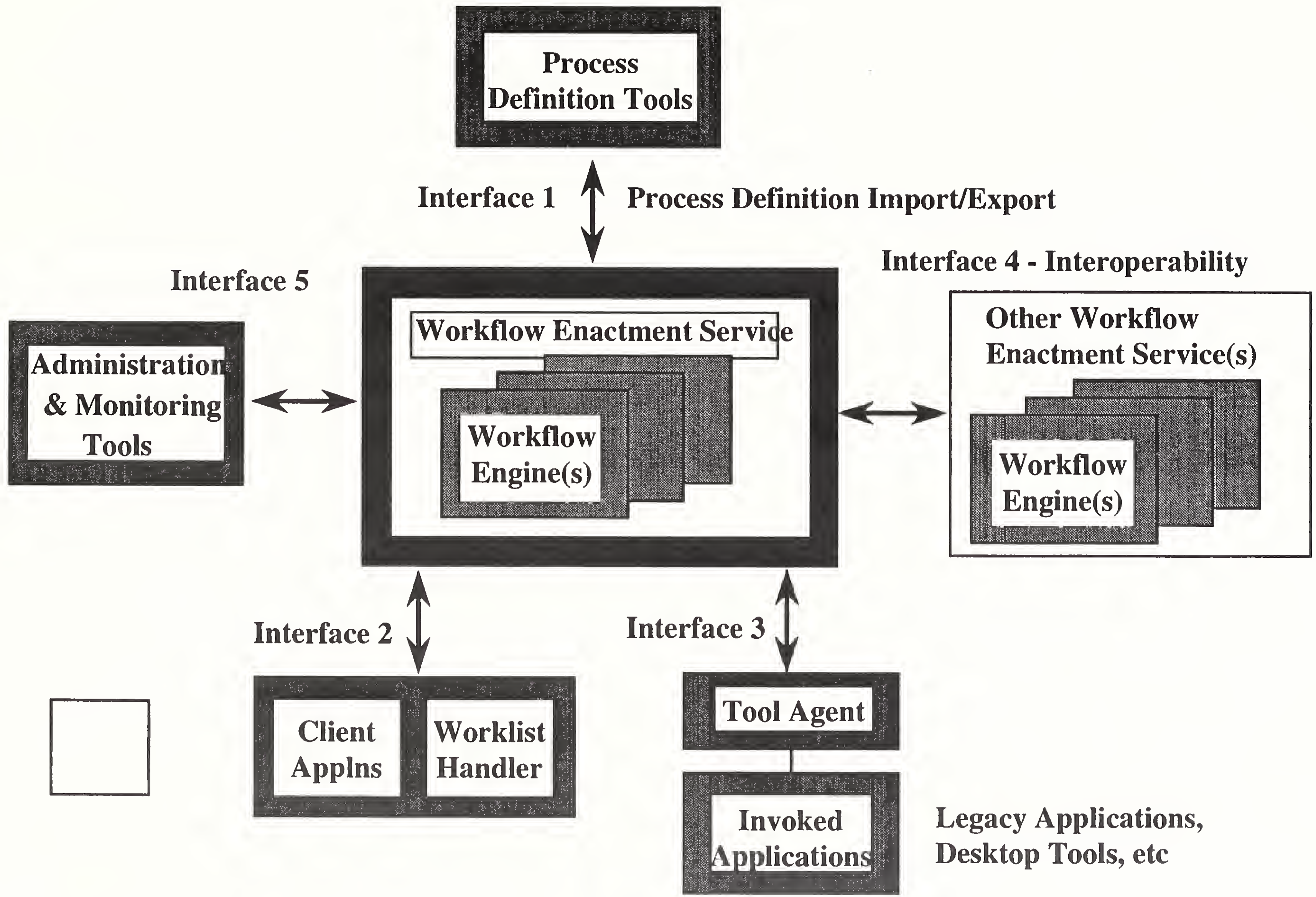
Background on the WfMC

- *Founded in 1993, to develop & promote workflow standards and market understanding*
- *Non profit-making, open to all*
- *Current membership is c. 220, representing:*





The Workflow Reference Model



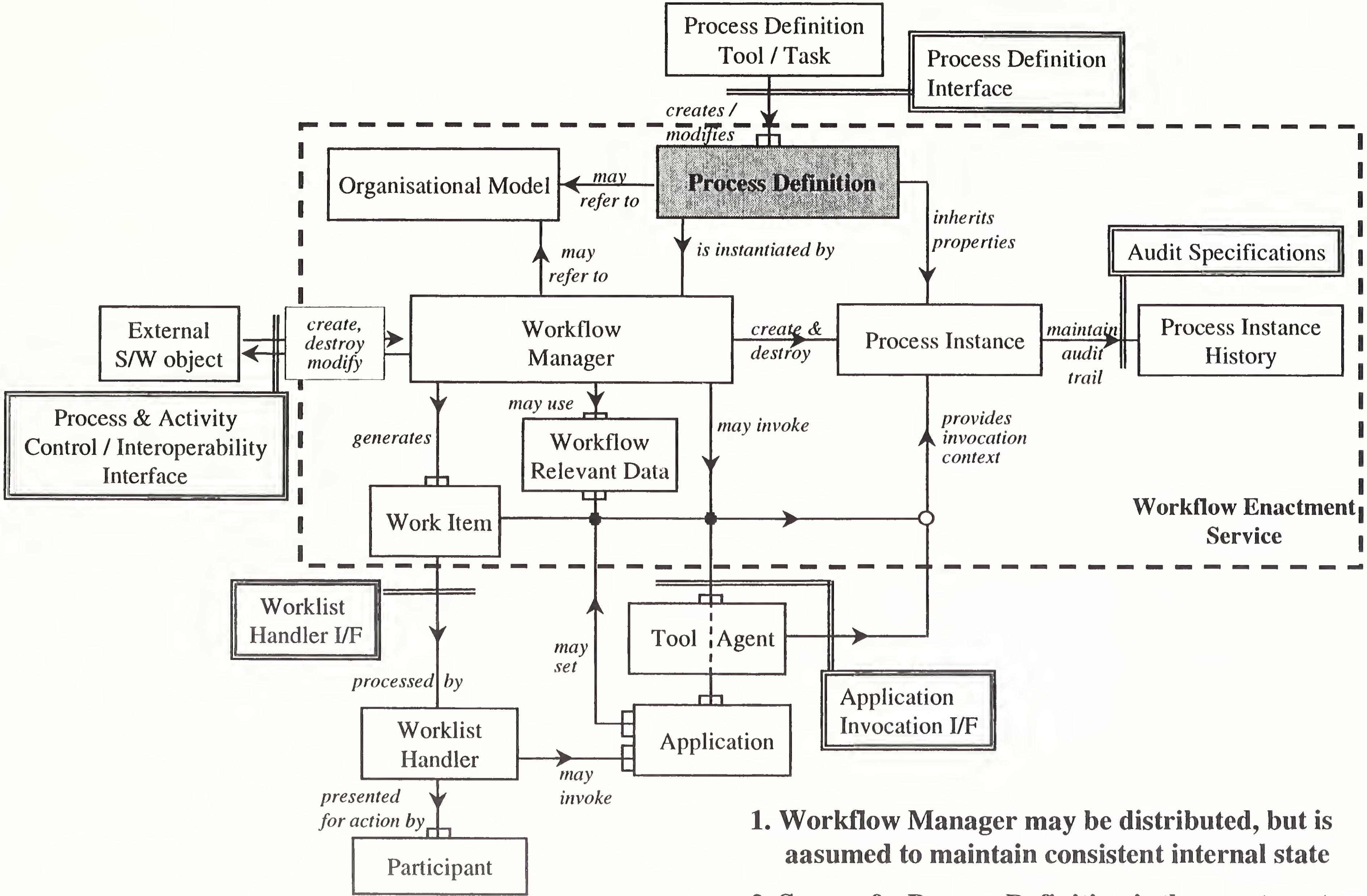
WfMC

WfMC - Documentation

- *Specifications:*
  - *Reference Model (1994)*
  - *Glossary (1994)*
  - *Workflow APIs (1995)*
  - *Interoperability Protocol & Bindings (1995)*
  - *Audit specification (1996)*
  - *Process Definition Import/Export Specification (1998)*
  - *Object Model and IDL (OMG submission, 1998)*

- *White Papers:*
  - *Interoperability (1994)*
  - *Security (1997)*
  - *Common Object Model (1998)*

Process Definition Context



1. Workflow Manager may be distributed, but is aasumed to maintain consistent internal state

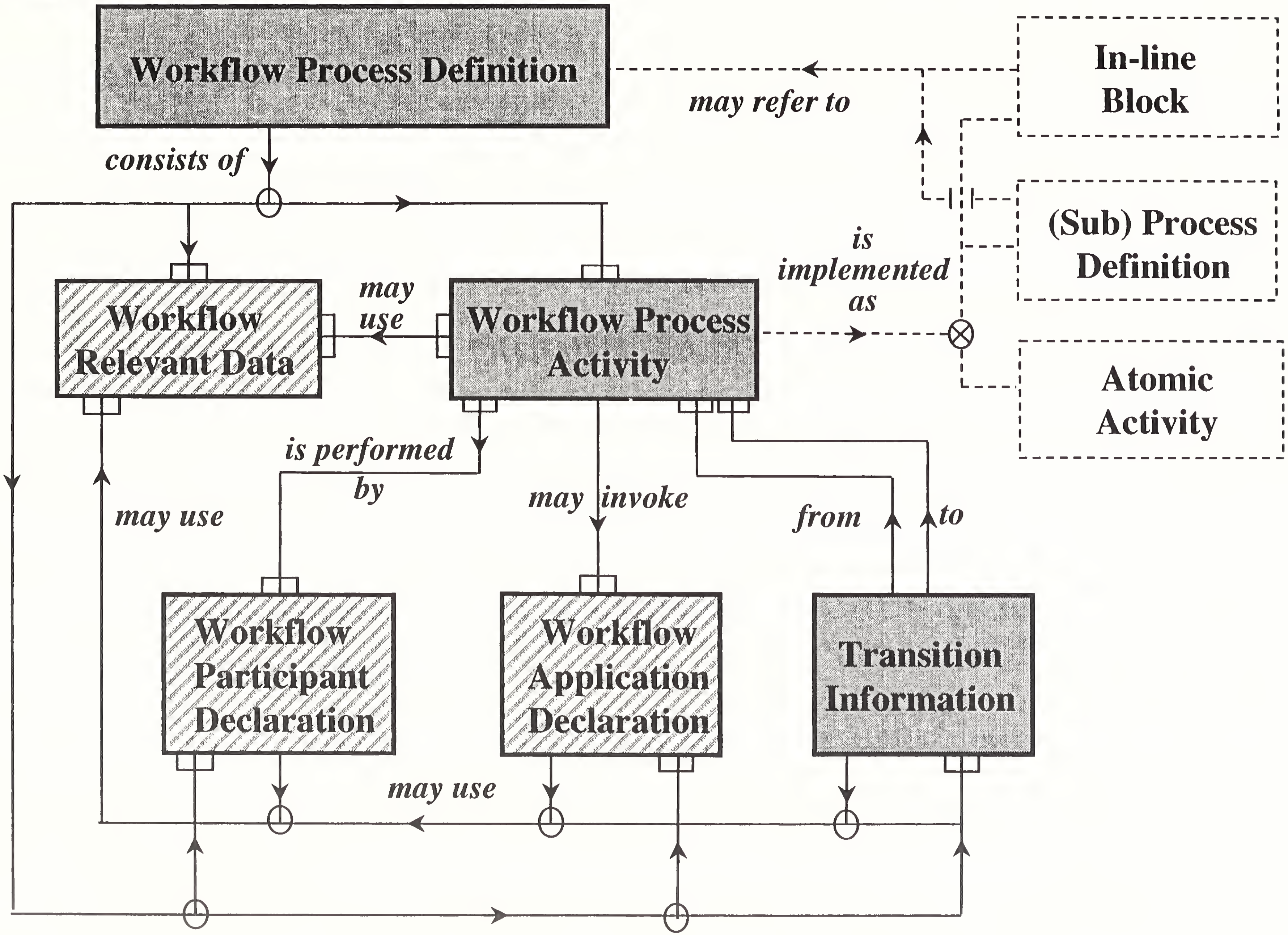
2. Scope of a Process Definition is the enactment service

WfMC

Process Definition Interchange

- ***Purpose***
  - *Exchange of process information between BPR tools, workflow systems, process definition repositories*
- ***Process Definition Meta-Model***
  - *Defines objects, attributes & relationships*
  - *Core Set plus extensible attributes*
- ***WPDL***
  - *Grammar for transfer of process definition objects & attributes*
- ***Process Definition Manipulation APIs***
  - *APIs for reading & writing object & attribute data*
- ***Other Representation Options?***
  - *UML, XML have been discussed*

Process Definition Meta-Model



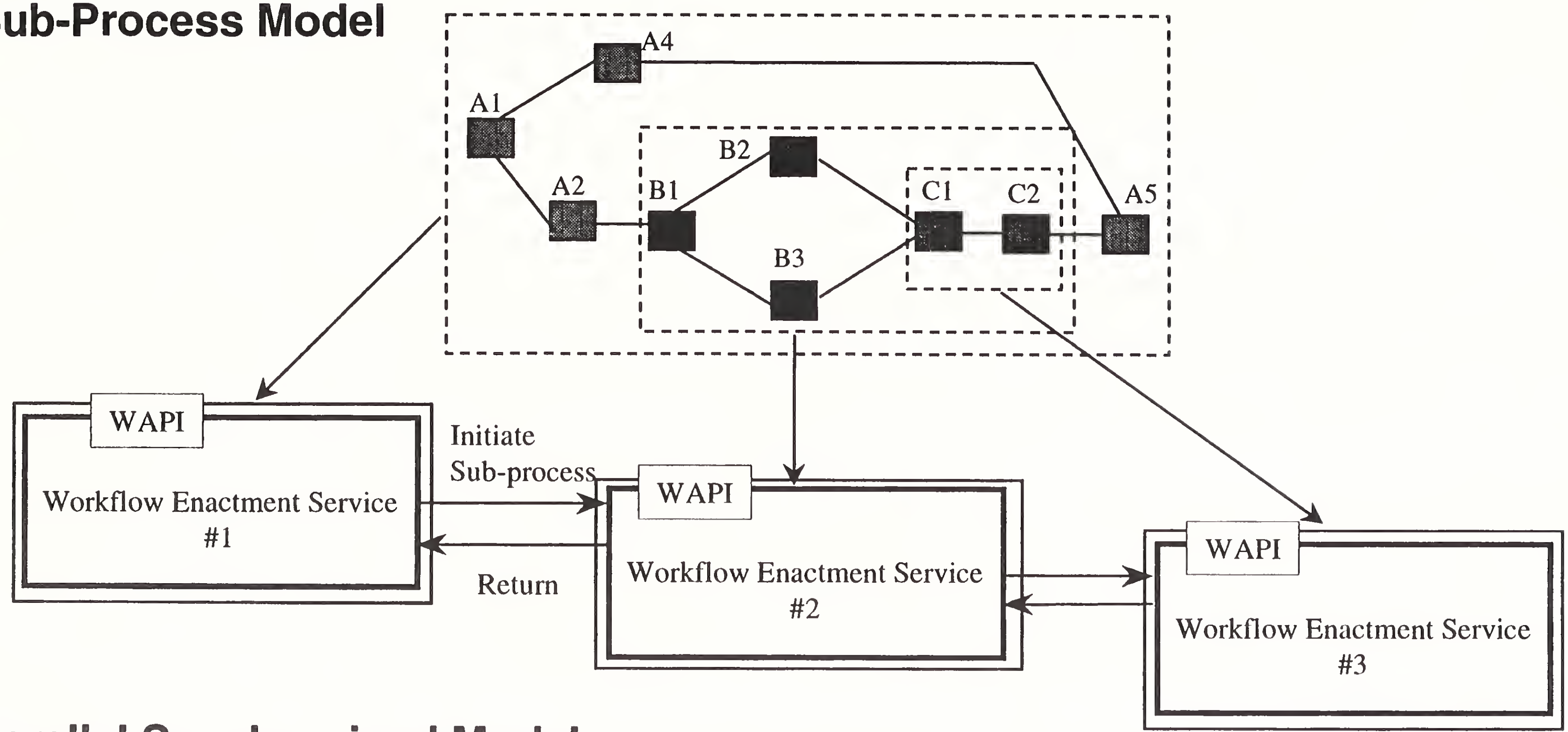
WfMC

Process Naming & Context

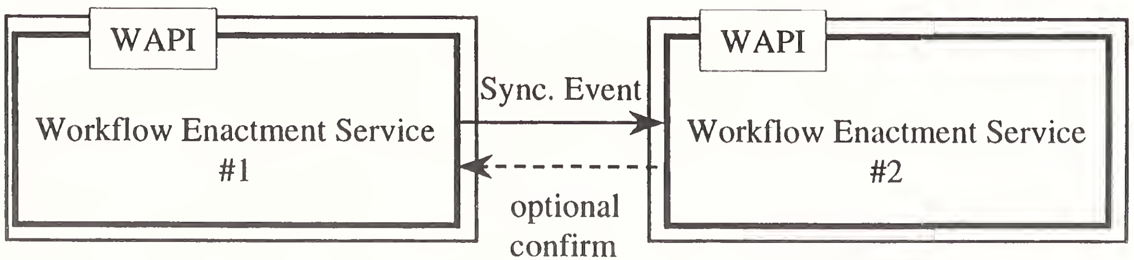
- ❑ *Activities may be atomic, sub-process call, or in-line block*
- ❑ *A sub-process inherits characteristics from its process definition and has its own name space apart from "Root Process Id" (from initiating process)*
- ❑ *A sub-process call may be specified as synchronous or asynchronous, binding prefixed or late*
- ❑ *An in-line block operates within the name space and characteristics of its local process*
- ❑ *Activity and Transition Ids are unique within a process definition*
- ❑ *Resource naming may use an Organisational Model - typically unique to a workflow enactment service*

Process Distribution & Interoperability

1. Sub-Process Model



2. Parallel Synchronised Model



WfMC

WPDL Overview

- *Grammar presented in Extended BNF notation*
- *Entities expressed by keywords, attributes by value pairs*
- *Data type structure*
  - *Simple - string, integer, float, reference, date/time (inc. boolean relationships)*
  - *Complex - array, record, enumeration, list*
- *Expressions*
  - *Logical and arithmetical operations permitted - for conditions*
- *Extended Attributes may be defined*
- *Library Procedures may be defined*
- *Interchange as ASCII character file*

WfMC

WPDL Sample

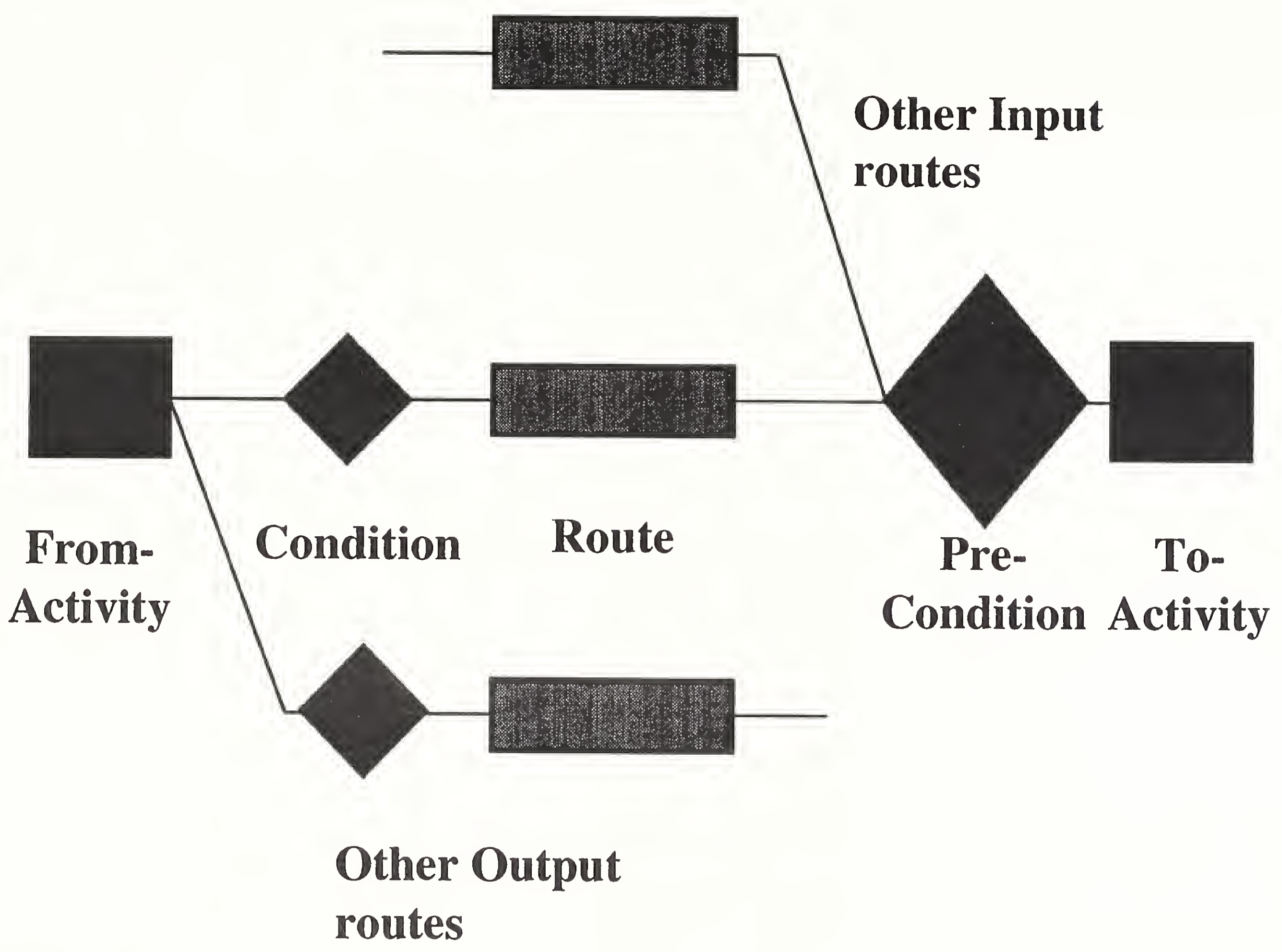
```
<Activity List>      ::=

ACTIVITY      <activity id>
      IMPLEMENTATION       <NO|APPLICATIONS<generic tool list>|
                                  WORKFLOW<subflow reference>>
      [DESCRIPTION         <description>]
      [NAME                <name>]
      [DOCUMENTATION       <documentation>]
      [ICON                <icon identifier>]
      [PERFORMER           <participant assignment>]
      [START_MODE          <AUTOMATIC|MANUAL>]
      [FINISH_MODE         <AUTOMATIC|MANUAL>]
      [INSTANTIATION       <ONCE|MULTIPLE>]
      [PRIORITY            <priority>]
      [<time estimation>]
      [COST                <cost estimation>]
      [<extended attribute list>]
END_ACTIVITY
      <subflow reference> ::=    ASYNCHR | SYNCHR  [BINDING LATE |
                                 IMMEDIATE] <process id> [<parameter map list>]
```

WfMC

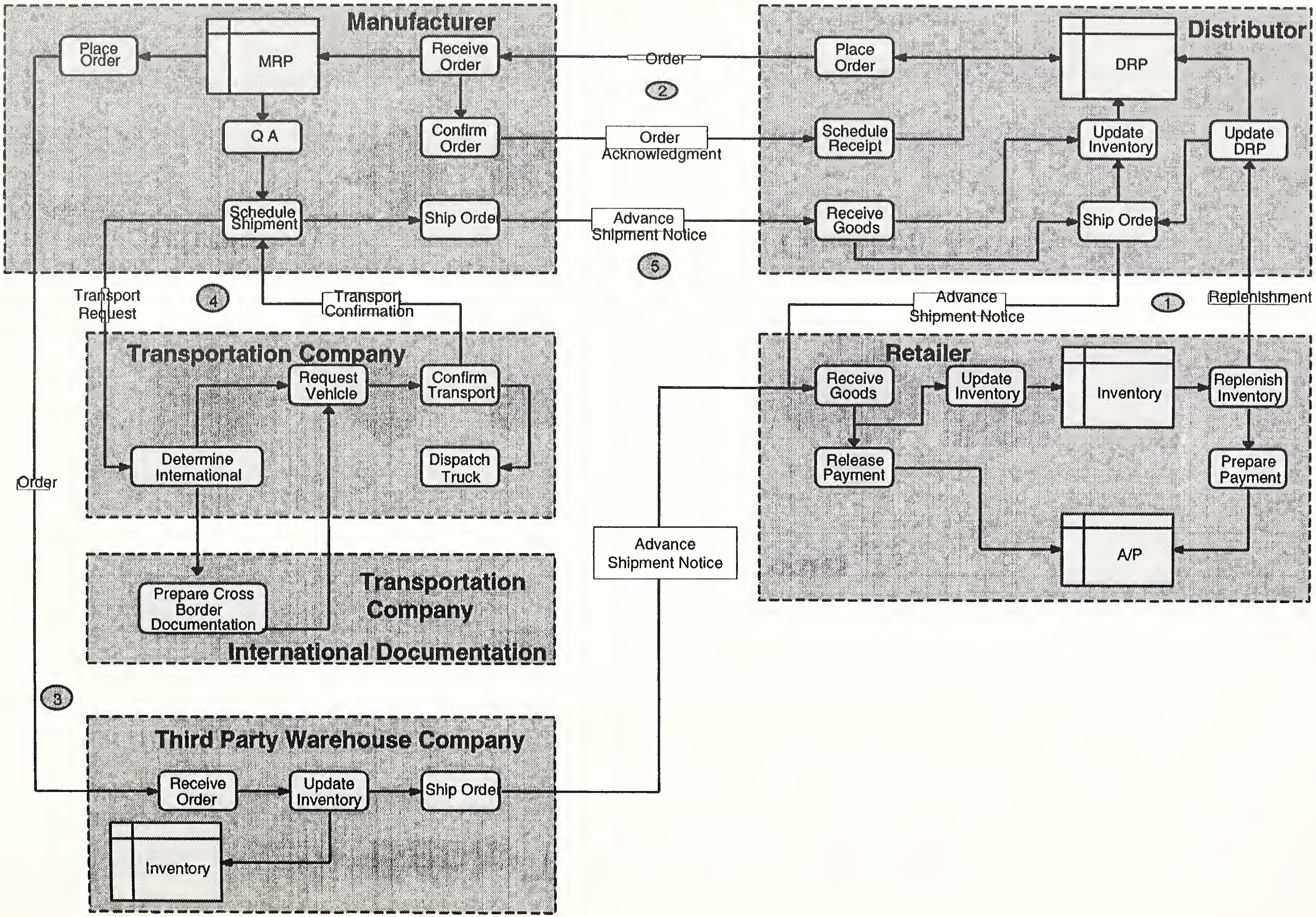
Issues and Complexities

- ***Dynamic versus predefined process behaviour***
  - *Production workflow typically tightly pre-defined*
  - *Ad-hoc workflow typically dynamic*
  - *Some vendors allow pre-defined (but limited) variation in runtime behaviour*
- ***Defining workitem structure and behaviour within an Activity***
  - *Various scripting approaches*
  - *Parallel/Sequential work-item behaviour*
- ***Defining control flow and transition behaviour***
  - *Block Structure*
  - *Free-form graph*
  - *Implicit parallel structure with pre-conditions*

Basic Transition Model



The Supply Chain Process Model



WfMC

Future Direction

- ❑ *Increasing co-operation with other industry bodies*
  - *OMG*
  - *AIIM*
  - *SPIRIT group*

- ❑ *Extensions for event synchronisation and peer interoperability, distributed object model*

- ❑ *Opportunities for formalisation of standards & product conformance work*

Web: WWW.WfMC.ORG
Email: WfMC@WfMC.ORG

Process Specification Language: Overview and Current Status

Craig Schlenoff, NIST

Mr. Schlenoff is a mechanical engineer at the National Institute of Standards and Technology (NIST) working in the Manufacturing Systems Integration Division (MSID). He is currently the principal investigator of two projects. The first, entitled the Process Specification Language Project, is defining a neutral representation (a language) for manufacturing processes which could be used for the sharing of process information among all manufacturing functions. The second, entitled Ontologies for Interoperabilities, is applying the principle of ontological engineering to manufacturing systems integration with the output being an ontology/taxonomy of manufacturing concepts and functions to provide a common, shared vocabulary of terms and meanings for manufacturing systems integrators.

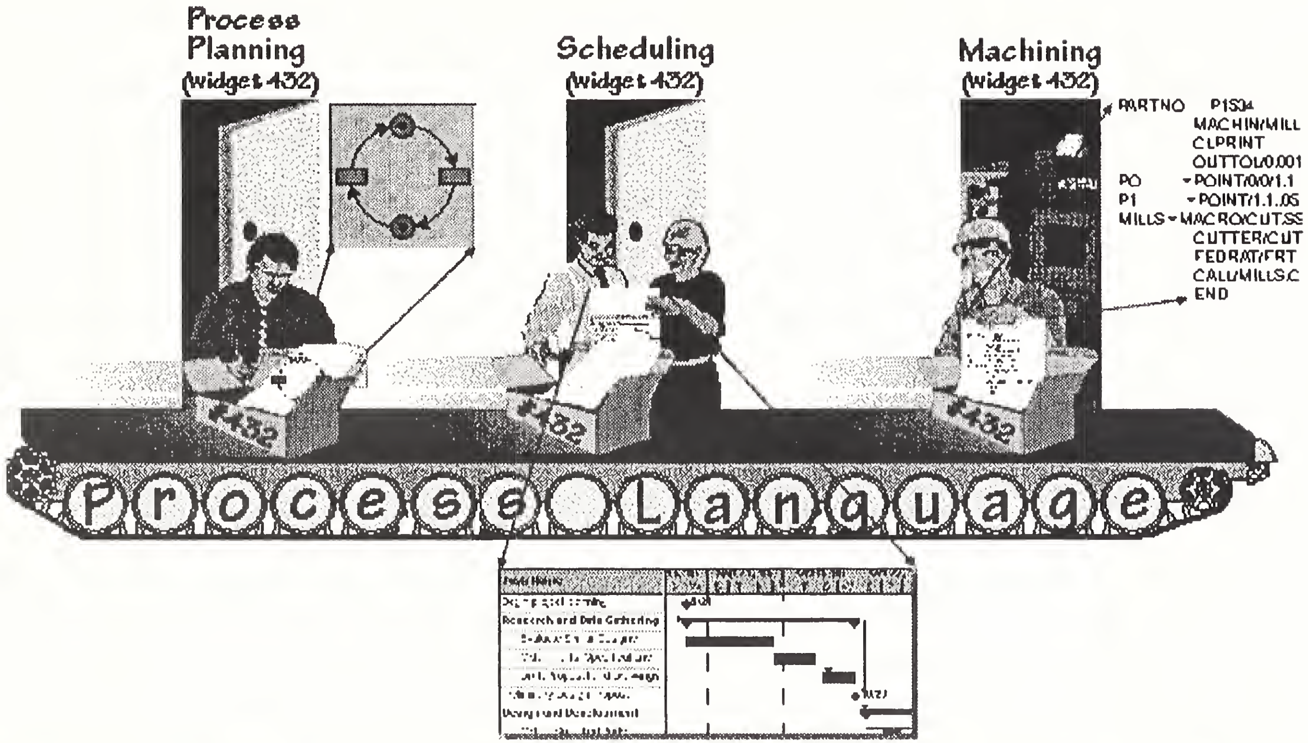
Mr. Schlenoff received his Masters degree from Rensselaer Polytechnic Institute (RPI) in mechanical engineering. While there, he performed research with Dr. Martin Hardwick in the Laboratory of Industrial Innovation researching STEP and particularly AP203. He was co-developer of the EXPRESS-V and later the EXPRESS-X languages which automates the mapping between any two EXPRESS schemas. He was also involved in the National Industrial Information Infrastructure Protocols (NIIIP) project. Prior to his work at RPI, he received his bachelors degree from the University of Maryland at College Park in mechanical engineering.

Mr. Schlenoff's expertise include process specification, process planning, ontologies and ontological engineering, STEP, AP203, applications of the Internet for collaboration, and other disciplines in the manufacturing realm.

Process Specification Language: Overview and Current Status

Craig Schlenoff

March 12, 1998



PSL

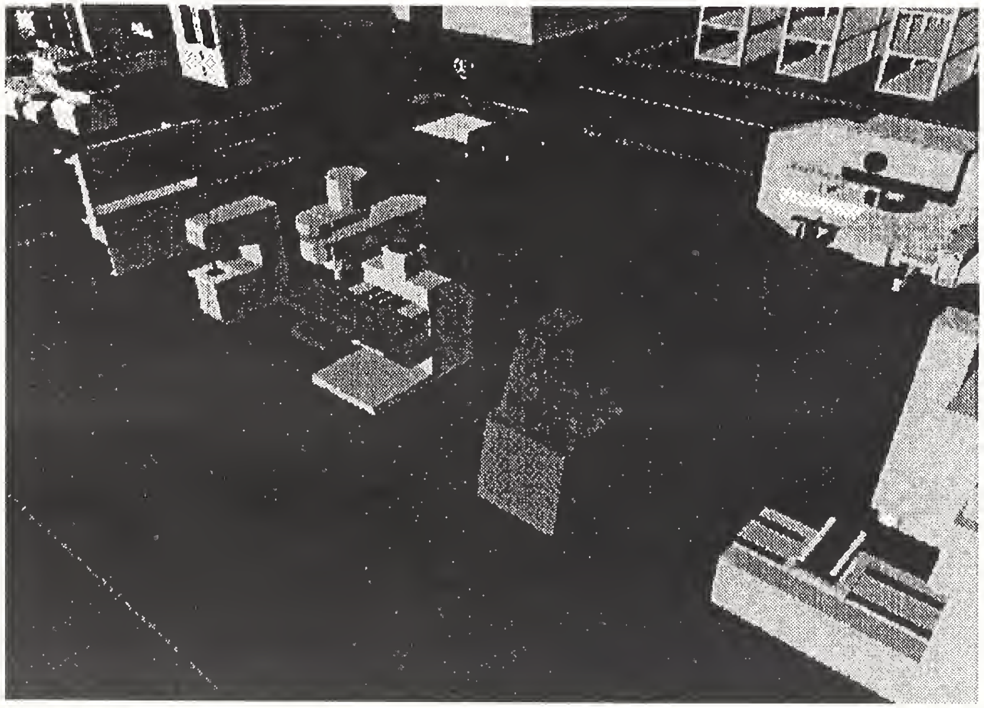
Outline

- Project Goals and Technical Plan
- Phase 1: Requirements Gathering
- Phase 2: Existing Process Representation Analysis
- PSL Roundtable
- Phase 3: Language Creation
- Concluding Remarks

PSL

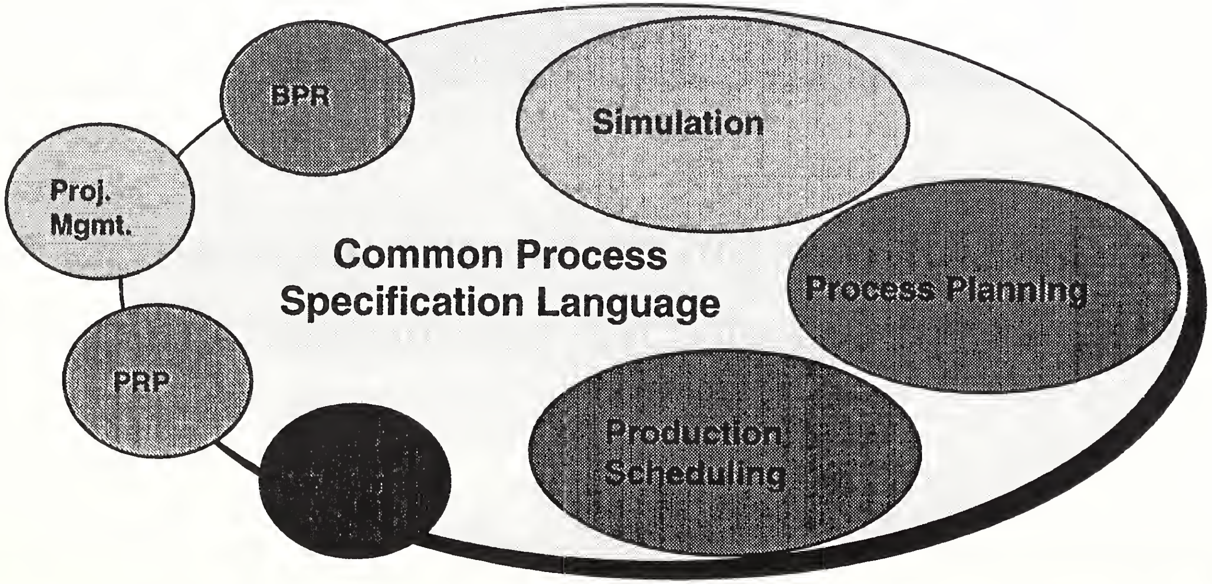
Goal

- To enable integration and interoperability of process-related information among manufacturing applications



How?

- By creating a process specification language that can serve as a neutral representation to allow for the automated exchange of process information among manufacturing systems.



Technical Phases

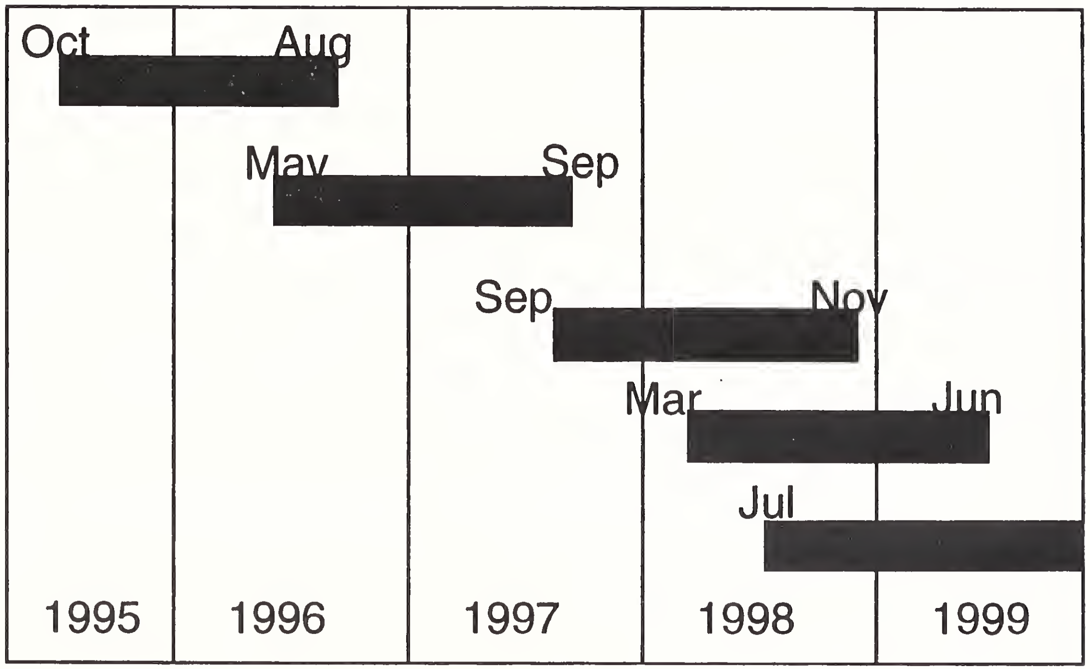
① Requirements Gathering

② Existing Process Representation Analysis

③ Language Creation

④ Pilot Implementation(s) and PSL Validation

⑤ Standardization



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Definitions

- **Process Specification Language - a language with which to specify a flow of processes. This may be done for prescriptive or descriptive purposes and is composed of well-defined semantics with one or more notations.**

- Process Characterization Model - a model describing the behavior and capabilities of a process independent of any specific application.

Phase 1: Requirements Gathering Goals

- Determine if there exists a common set of requirements for specifying processes
- Categorize these requirements in a logical, cohesive fashion

Phase 1: Requirements Gathering Approach

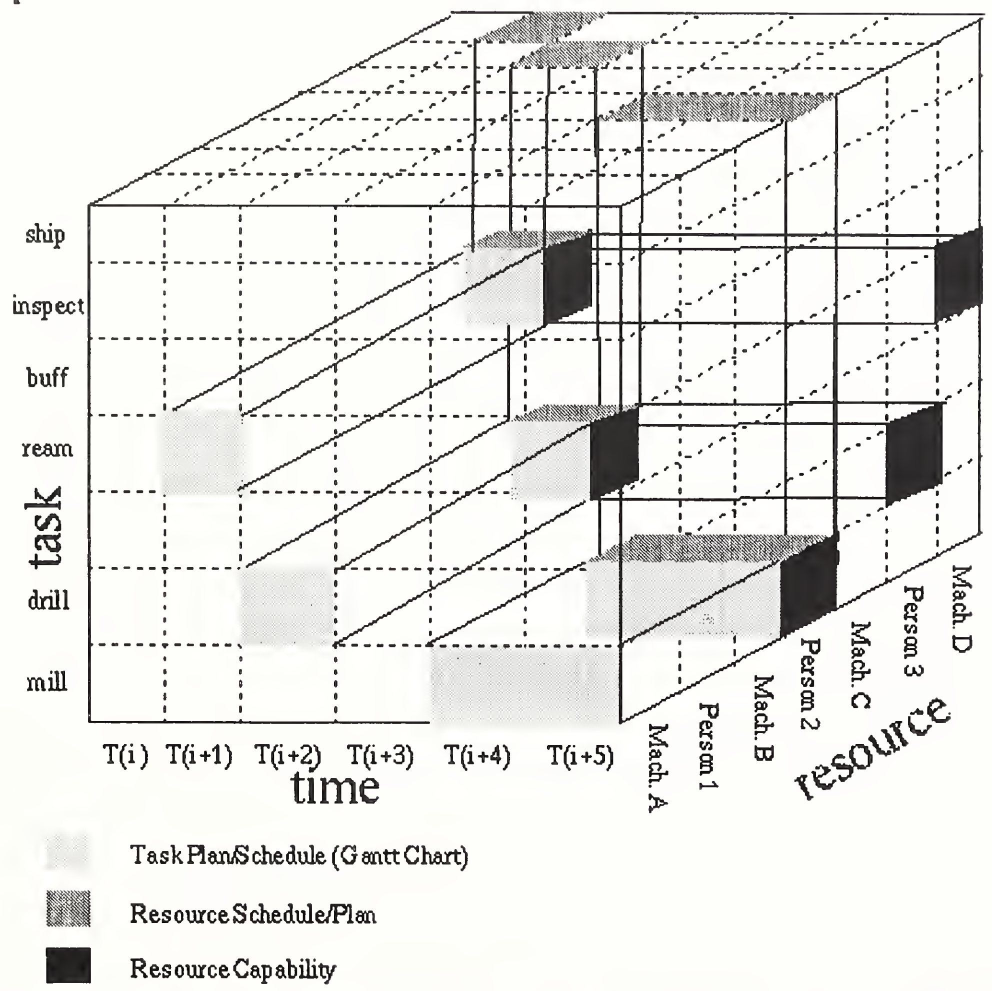
- Explore a cross-section of manufacturing applications
  - Manufacturing Process Planning, Production Scheduling, Simulation, Product Realization Process Modeling, Business Process Re-Engineering, Project Management, Work Flow
  - Speak with researchers who have gathered similar requirements to represent process but limited their scope to particular industries
  - Examine existing software packages, modeling languages, architectures, and standards

Phase 1: Requirements Gathering Categories and Examples of Requirements

Categories	Representational	Functional
Core	e.g., resource	e.g., extensibility
Outer Core	e.g., conditional task	e.g., exception handling
Extensions*	e.g., process performance measurements (Analysis)	e.g., resource monitoring & feedback (Analysis)
Application	e.g., non-machining times (Scheduling)	e.g., dynamic rescheduling (Scheduling)

*Extensions: 1) Administrative/Business, 2) Planning/Scheduling/Quality/Analysis, 3) Real-Time/Dynamic, 4) Process Intent, 5) Aggregate Resources, 6) Stochastic/Statistics

Process Cube (for a single product)



Phase 1: Requirements Gathering Concluding Observations

- Significant overlap in requirements necessary for representing processes among the applications under study
- Supports the supposition that a common process specification is feasible
- All of the core and most of the outer core requirements appear to have general applicability to applications far beyond the manufacturing domain
- The set of requirements is useful for other purposes, e.g., Raytheon MSD, Toronto TOVE Ontology

Phase 2: Process Representation Analysis Goals

- Identify how process requirements are captured within existing representations
- Identify a representation or combination of representations that provide the best coverage of the requirements
- Identify gaps in existing representations' abilities to address process specification requirements
- Understand what types of representations provide the best coverage of certain requirements

Phase 2: Process Representations Studied

- ACT
- A Language for Process Specification
- AP213
- Behavior Diagrams
- Core Plan Representation (CPR)
- Entity-Relationship (E-R)
- EPFL Petri Net Representation
- Functional Flow Block Diagrams
- Gantt Charts
- Generalized Activity Networks (GAN)
- Hierarchical Task Networks (HTN)
- IDEF0
- IDEF3
- <I-N-OVA> Constraint Model
- Knowledge Interchange Format
- O-Plan Task Formalism
- OZONE
- PAct
- PAR2
- Part 49
- PERT Networks
- Petri Nets
- Process Flow Representation
- Process Interchange Format V.1.1
- Quirk Model
- Visual Process Modeling Language
- AND/OR Graphs
- Data Flow Diagrams
- Directed Graphs
- State Transition Diagrams
- Tree Structures

Phase 2: Process Representation Analysis Procedure

- Created an online matrix to allow anyone in the world to easily add to or view the information in the matrix
- Relied on people who were very familiar with the various representations to help populate the matrix (20 total)
- Analyzed the information in the matrix to draw some high-level conclusions (i.e., what types of information are best captured by what types of representations)

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Phase 2: Process Representation Analysis Conclusions

- There are numerous ways of representing the same concept, depending on the approach.
- Nearly all representations focus on the syntax and presentations, they rarely specify exactly what the concept means.
- Object-based and constraint-based representations provided the best overall coverage of the requirements.

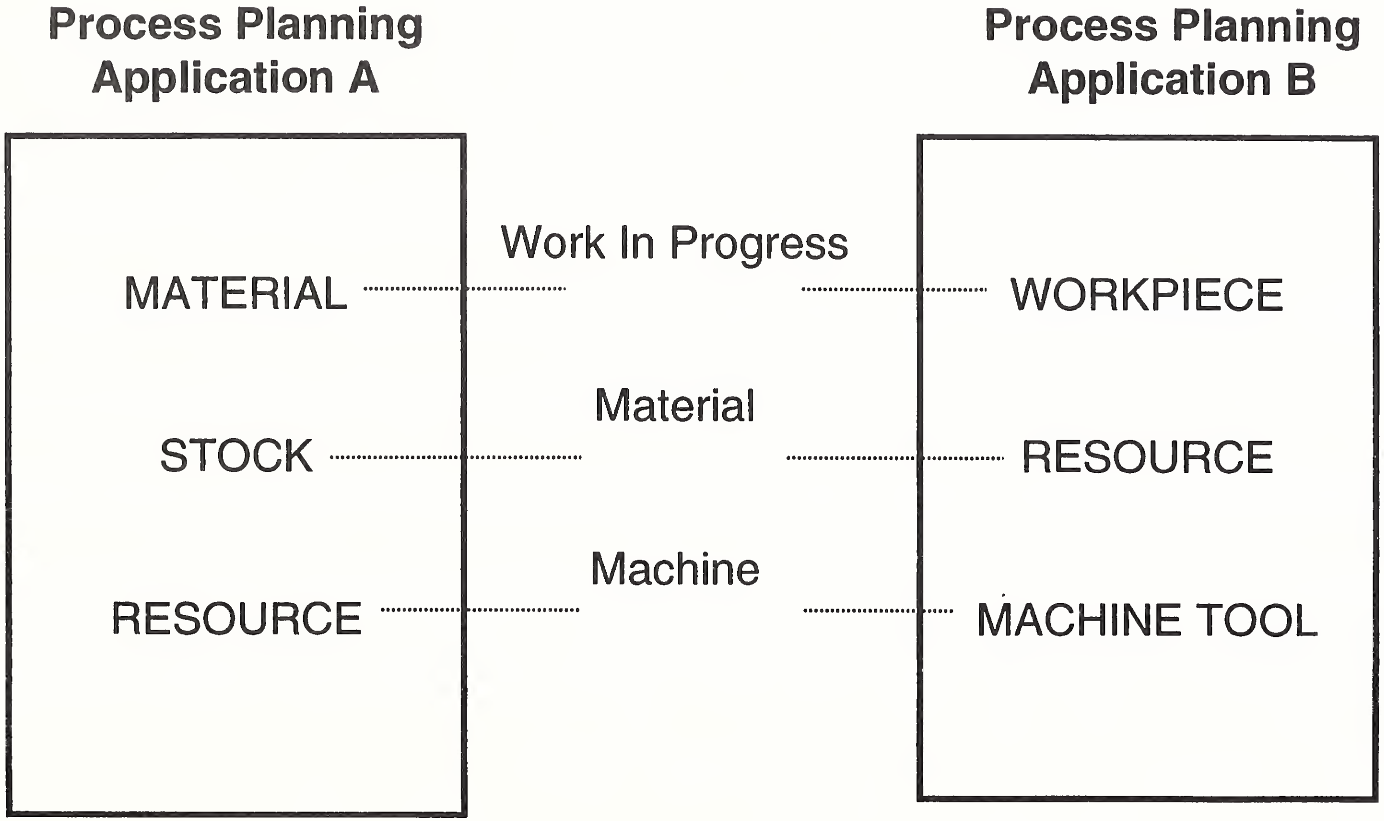
PSL Roundtable - April 1997
Overview

- To review results to date and to establish the PSL technical direction
- Attended by approximately 20 experts in various process representation related fields
- A mix of people from industry, academia, and government
- Virtual (via email, web pages) and Physical (at NIST) discussions

PSL Roundtable Results

- Phase 1 & 2 results provide good foundation upon which to proceed
- Based on Phase 1 & 2, can establish the PSL “core” , or the essential elements of processes
- To enable exchange of process information, these elements must be unambiguously defined

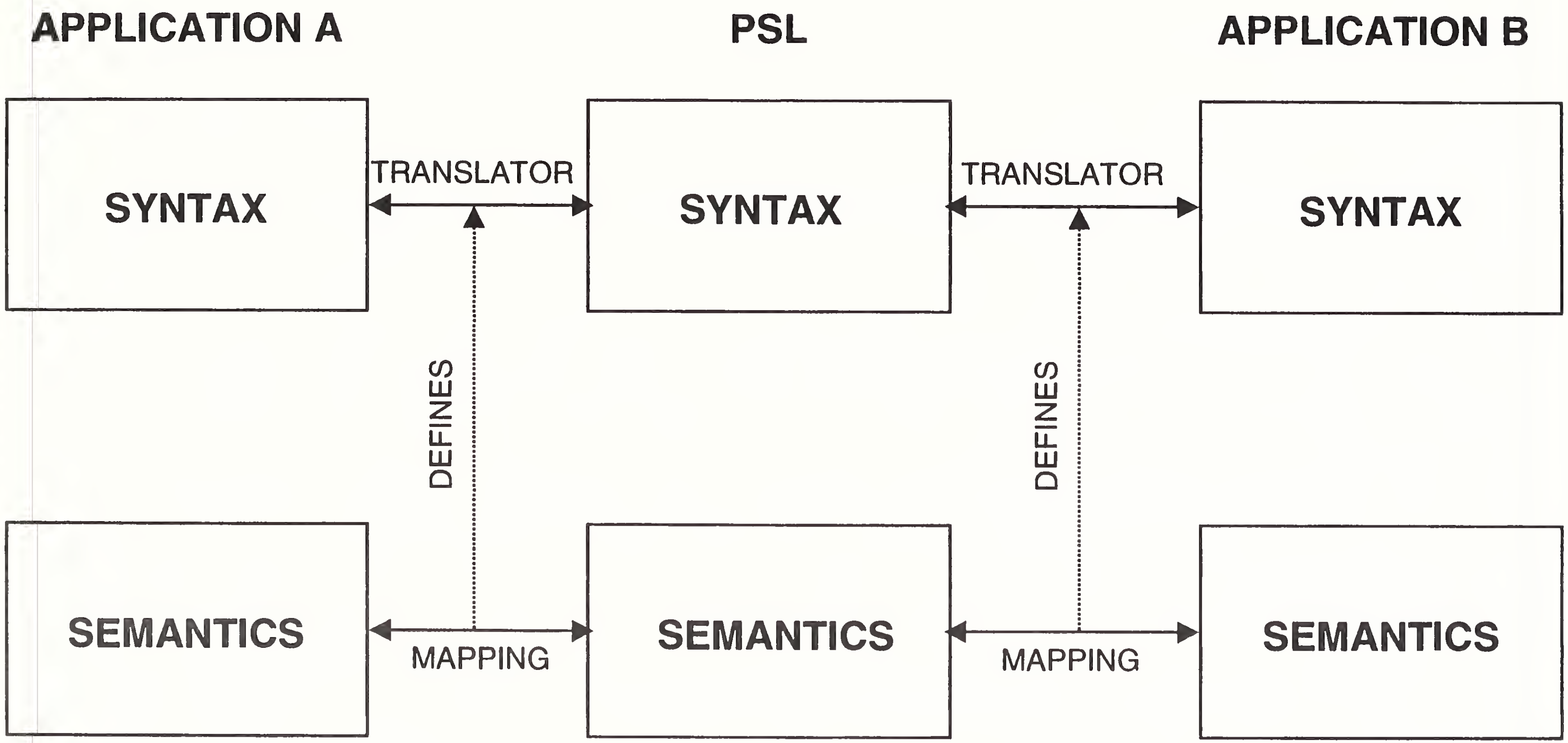
Why Semantics?



RESOURCE in Application A ≠ RESOURCE in Application B

Need to unambiguously capture meanings of terms for all current (and future) uses

PSL Exchange Scenario



Phase 3: Language Creation Stages of the Language Development

- Create or identify appropriate scenarios
- Identify and define the semantic concepts
- Develop one or many presentations (notations)

Phase 3: Language Creation
Identify Scenarios

- Purpose of Scenarios
  - facilitate the development and understanding of the semantic concepts
  - help to describe and understand both process specification requirements and representational approaches
  - ensure that the PSL truly addresses real-world requirements

Phase 3: Language Creation
Define Semantic Concepts

- Primitives
  - Entities
    - Activity
    - Object
    - Time point
  - Relations
    - Before
    - In
    - Part of
  - Functions
    - Beginof
    - Endof
- Defined Concepts
  - Process
  - Sequence
  - Resource
- Extensions
  - goals/intentions
  - durations
  - calendars
  - constraints
  - quantities/measurements
  - simple group

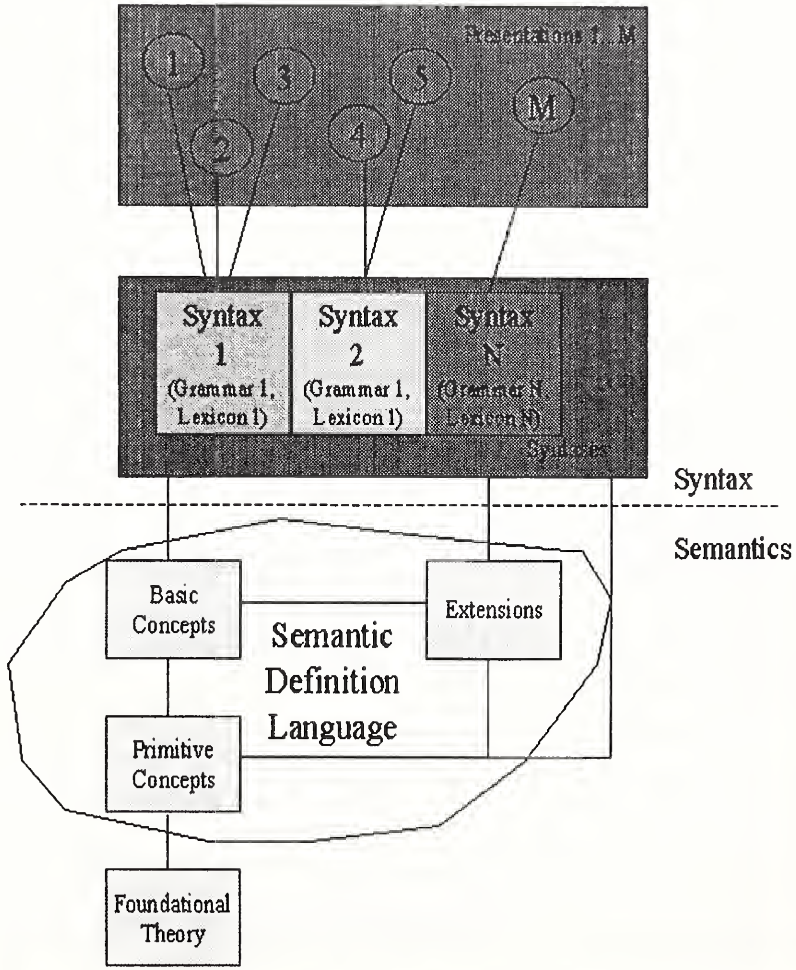
PSL

Phase 3: Language Creation
Develop Presentations

- Define a suggested mapping between the semantic concepts and the constructs within a given presentation
- Example presentations under investigation
  - Unified Modeling Language (UML)
  - Petri Nets
  - Constraints
  - IDEF3

"Baby" PSL

- A scaled-down version of the full PSL
- Only enough concepts to model a pre-determined scenario
- Will involve:
  - determination and definition of necessary semantic concepts;
  - development of a default language encoding;
  - mappings from the semantic concepts to two presentations.



On-Going External Contacts

- Boeing
- George Washington University
- Knowledge Based Systems, Inc.
- Motorola
- PIF (Process Interchange Format) Working Group
- Raytheon
- Teknowledge Corp.
- University of Edinburgh, AIAI
- University of Maryland, College Park
- University of Toronto

Concluding Remarks

- The PSL is being developed by a growing group of collaborators
- The next release of Process Interchange Format (PIF) and the "baby" PSL will have an identical core
- Results from Phase 1 and 2 contributing to other related projects (e.g., Raytheon MSD, TOVE, SPAR)
- Current progress is always available through our web pages **http://www.nist.gov/psl/**
- Seeking both vendors and industrial partners for pilot implementations
- Feedback is always welcome and encouraged!

PSL

Further Questions?

Craig Schlenoff
craig.schlenoff@nist.gov
(301) 975-6536

Amy Knutilla
amy.knutilla@nist.gov
(301) 975-3514

Dr. Steven Ray
ray@nist.gov
(301) 975-3524

What we have here is a failure to communicate

Anne Jones, Wizdom Systems, Inc.

Anne Jones is a Registered Nurse with over twenty years' experience in a variety of clinical and administrative settings. She joined Wizdom Systems, Inc. two years ago and is now the Director of Medical Services, concentrating on consulting in Business Process Reengineering for the healthcare industry. Anne holds a Bachelor's degree in Nursing and a Master's degree in Philosophy.

Wizdom Systems, Inc. was founded by Dennis E. Wisnosky, who co-developed the US Air Force Integrated Computer Aided Manufacturing Program in 1976. From this program emerged the Integrated Definition Language (IDEF) modeling and analysis technique. IDEF is now the Federal Information Processing Standard (FIPS) for modeling techniques and is the most widely used methodology for process redesign and reengineering. Wizdom has an excellent industry-wide reputation and has been providing high quality process reengineering products and services to a broad clientele for over ten years.

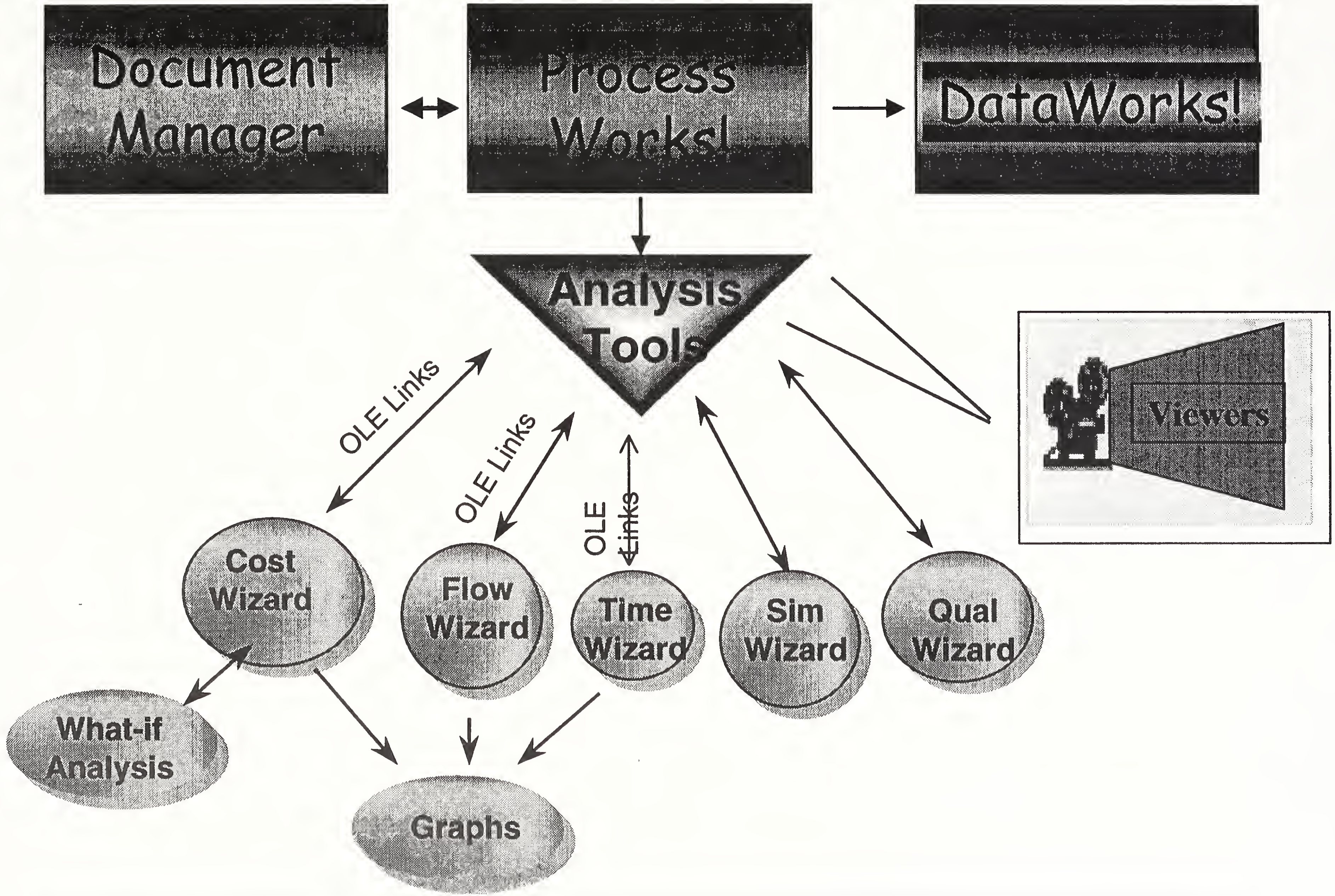
What we have here is a failure to communicate

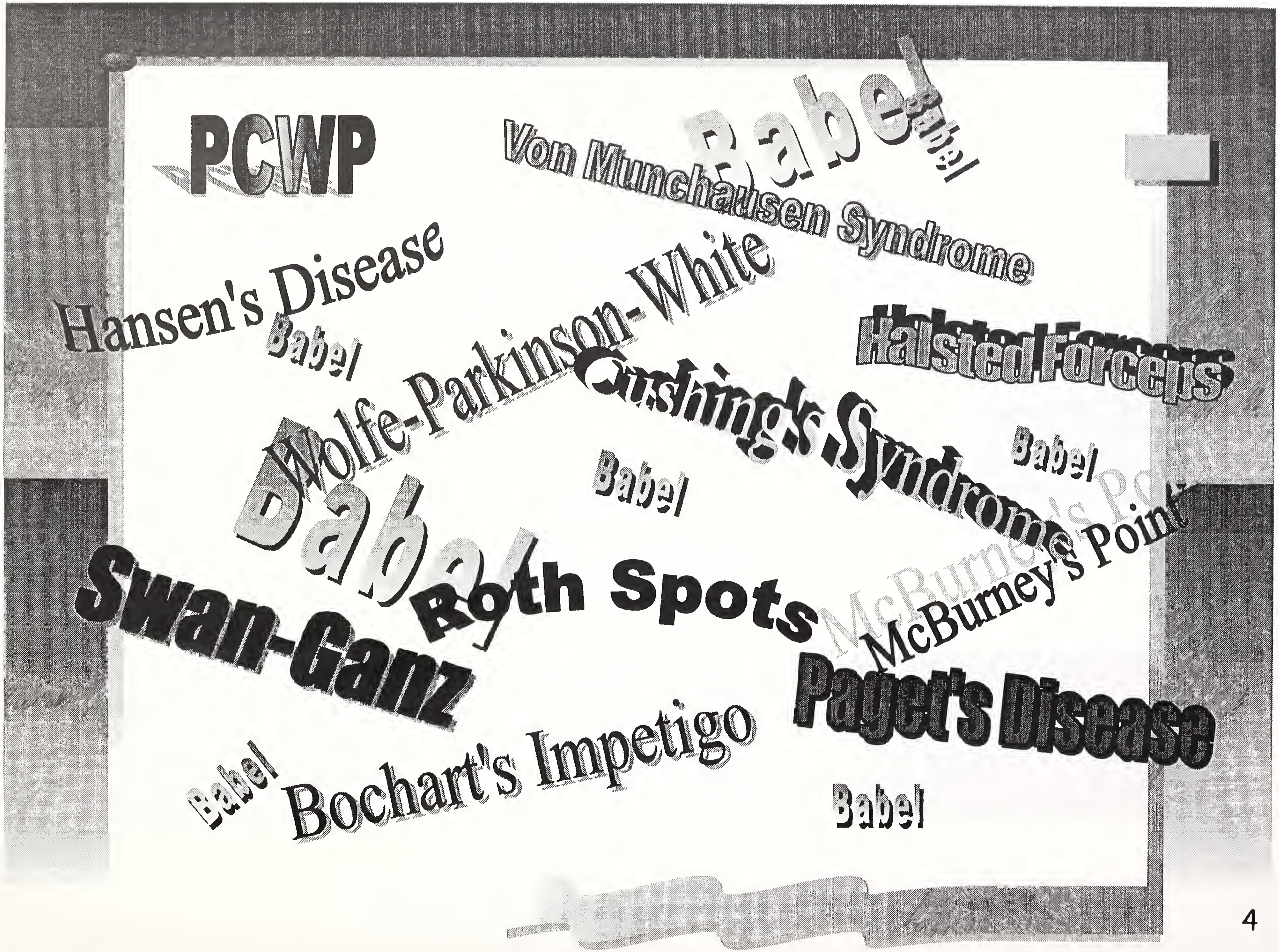
Anne Jones RN, MA
Director of Medical Services
Wizdom Systems, Inc

Outline:

- Introduction
- Language-- it's a virus
- Healthcare versus manufacturing
- Improving communication
- Conclusion

WizdomWorks98!




PCWP
Von Munchausen Syndrome
Babel
Babel
Hansen's Disease
Babel
Wolfe-Parkinson-White
Cushing's Syndrome
Halsted Forceps
Babel
Babel
Babel
Roth Spots
McBurney's Point
McBurney's Point
Swan-Ganz
Paget's Disease
Babel
Bochart's Impetigo
Babel

Lost in the Translation:

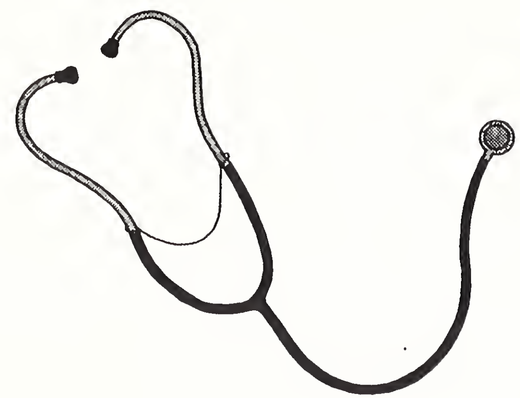
- "It takes a strong man to make a tender chicken"
- "It takes an aroused man to make a chicken affectionate"

- Scandinavian vacuum cleaner manufacturer Electrolux uses the following in American ad campaign:
- "Nothing sucks like an Electrolux"

CPR: An example

- Core Plan Representation
- Computer-aided Process Reengineering
- Computerized Patient Record
- Cardio-pulmonary Resuscitation

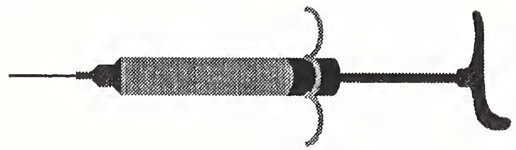
Common Functional Requirements:



- Staff and HR
- Supplies
- Financial management and planning
- Outcomes and variance tracking
- Process planning and re-design

Healthcare Differences:

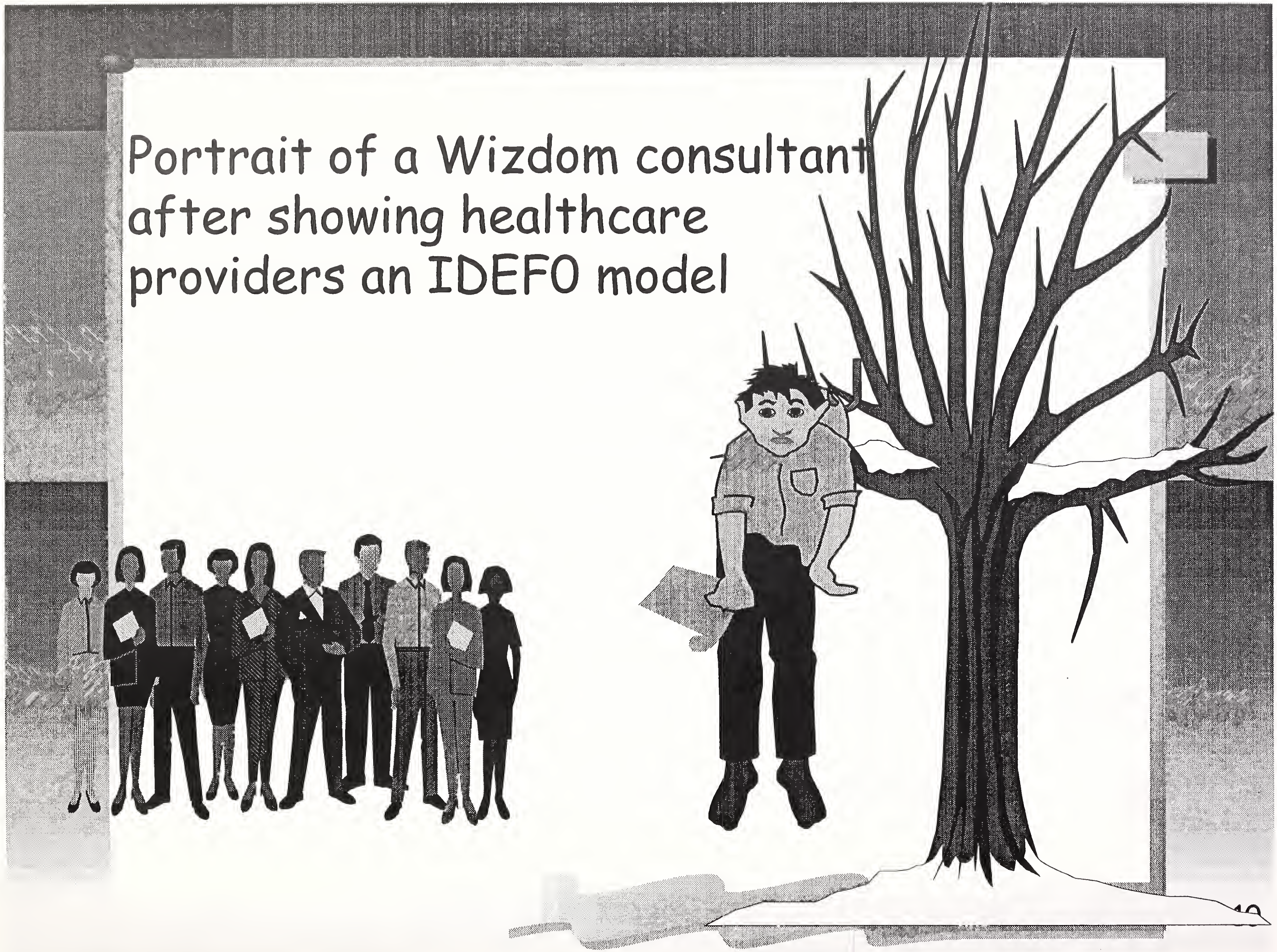
- Input, output, and throughput of HC process is people
- Widgets don't whine



- More litigious climate
- Healthcare is usually more urgent and more variable

Healthcare, continued:

- The process owners may not be employees
- Some non-employees have all overhead costs paid for by the organization
- Process owners often have less control over outcomes


Portrait of a Wizdom consultant
after showing healthcare
providers an IDEF0 model

An End-user's Perspective

- PSL
- Product-independent standards
- Tool use

The second day of the workshop consisted of a tutorial titled, "An In-depth Look at Process Information Technology." The presenters on the second day, along with their biographies, are listed below. Their presentations follow the listing.

Perakath Benjamin, KBSI

As KBSI's Vice President for R&D, Dr. Perakath Benjamin provides technical leadership and direction to the organization's R&D initiatives. Dr. Benjamin is the Principle Investigator for the DARPA Virtual Enterprise Engineering Project that led to the development of advanced process management tools and a preliminary theory of process knowledge representation. The process knowledge representation work is continuing through the NIST PSL effort. Dr. Benjamin was one of the principal developers of the IDEF3 process modeling method and the IDEF5 ontology modeling method, emerging DoD standards for process and ontology modeling. Dr. Benjamin has been the PI on a number of R&D projects in knowledge-based simulation, planning and scheduling systems, AI applications manufacturing systems, activity based costing, process management methods and tools, and ontology management technology.

Christopher Menzel, KBSI

Christopher Menzel teaches in the philosophy department at Texas A&M University. His research interests are in the areas of mathematical and philosophical logic. His more theoretical interests concern the formal and philosophical issues surrounding quantified modal logic, and his more applied interests concern the application of formal methods to the modeling of large systems. He is particularly interested in the mathematical representation of dynamic information as a foundation for enterprise process modeling.

Amit Sheth, University of Georgia

Dr. Amit Sheth directs the Large Scale Distributed Information Systems Lab (LSDIS, http://lsdis.cs.uga.edu), is an Associate Professor of Computer Science at the University of Georgia, and is the President of Infocosm, Inc. (http://www.infocosm.com). Earlier he worked for nine years in the R&D labs at Bellcore, Unisys, and Honeywell. His research interests are in developing work coordination and collaboration systems through intelligent integration of collaboration (project METEOR), collaboration (project CaTCH) and information management technologies, and in enabling Infocosm through semantic interoperability, information brokering, and integration of heterogeneous digital media (project InfoQuilt). His research in academia has led to two commercial products. A selection of his professional activities include four recent conference/workshop keynotes in the areas of workflow management and semantic interoperability, organization of the National Science Foundation (NSF) workshop on Workflow and Process Automation in Information Systems, serving as a co-director of NATO ASI on Workflow Management Systems and Interoperability, and initiating (and serving as the steering committee chair of) the Association for Computing Machinery (ACM) International Joint Conference on Work Activities Coordination and Collaboration.

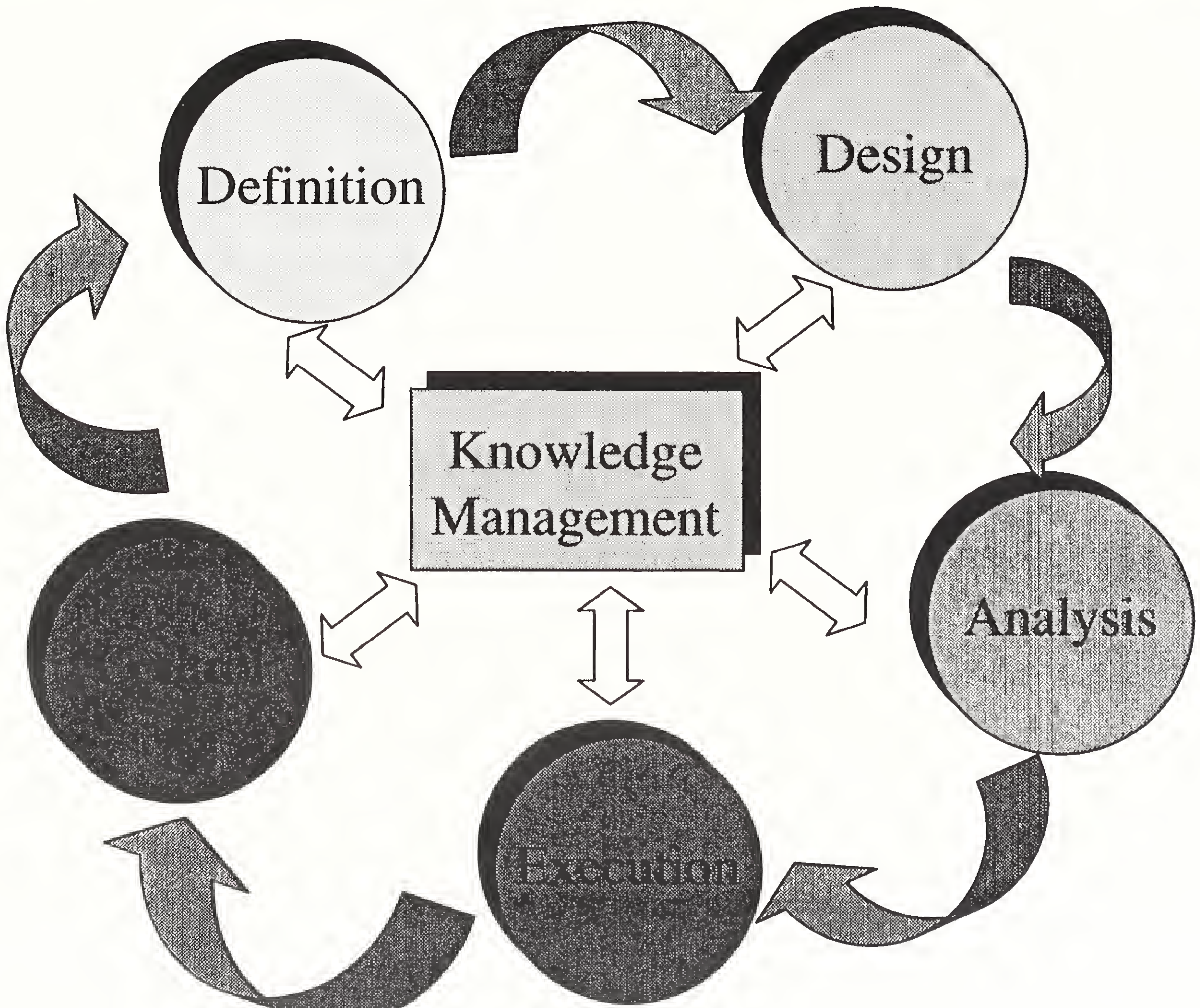
Methods and Tools for Process Analysis

Perakath Benjamin
Knowledge Based Systems, Inc.
pbenjamin@kbsi.com
www.kbsi.com

Outline

- Introduction
- Simulation modeling
- Activity based management
- Tool demonstrations
- Technical challenges

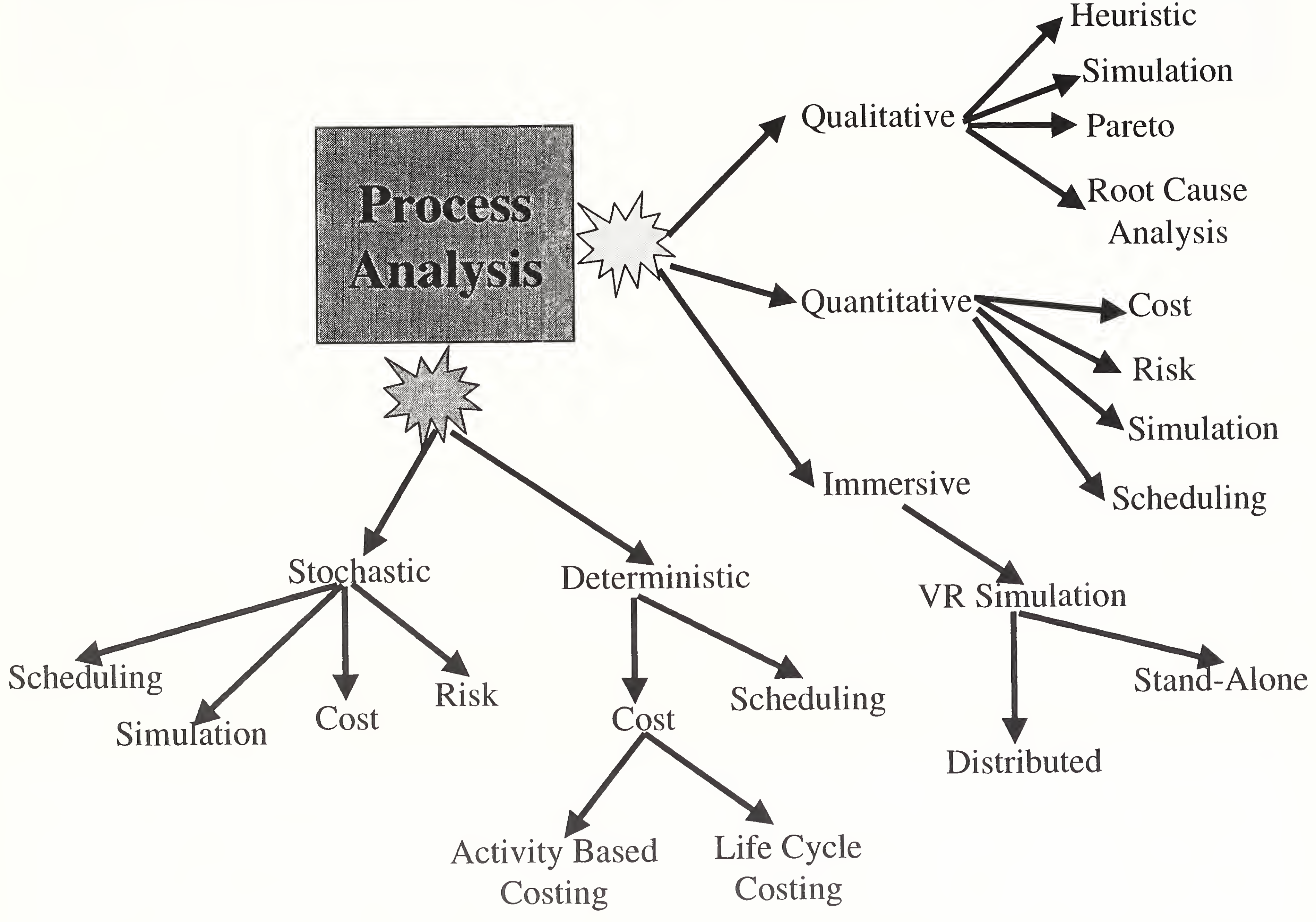
Process Technology - A Life Cycle Perspective



Process Analysis

- Evaluation of process performance relative to process intent
- Levels of analysis
  - Quantitative vs. qualitative vs. immersive
  - Stochastic vs. deterministic
- Multiple perspectives
  - Plan analysis, manufacturing process analysis, schedule analysis, workflow analysis, agent/software behavior analysis
- Multiple techniques and tools
  - Simulation, statistical methods, scheduling methods, cost modeling techniques, qualitative methods, immersive methods (VR-based)

Process Analysis Method Taxonomy



Introduction to Simulation Modeling

- Simulation Concepts
- The Simulation Modeling and Analysis Process
- Advantages and Disadvantages
- Applications
- Technical Challenges and Gaps
- Demonstration

What is Simulation?

- A method for conducting numerical experiments on a computer based on mathematical and logical representations of a system in order to evaluate the structure and behavior of the system over extended periods of time

Simulation Concepts

- **System**
  - facility or process of interest
- **Model**
  - an idealization of reality
  - developed for a specific purpose
- **Simulation**
  - a technique for experimenting with the model over time
  - to feign the essence, without the reality

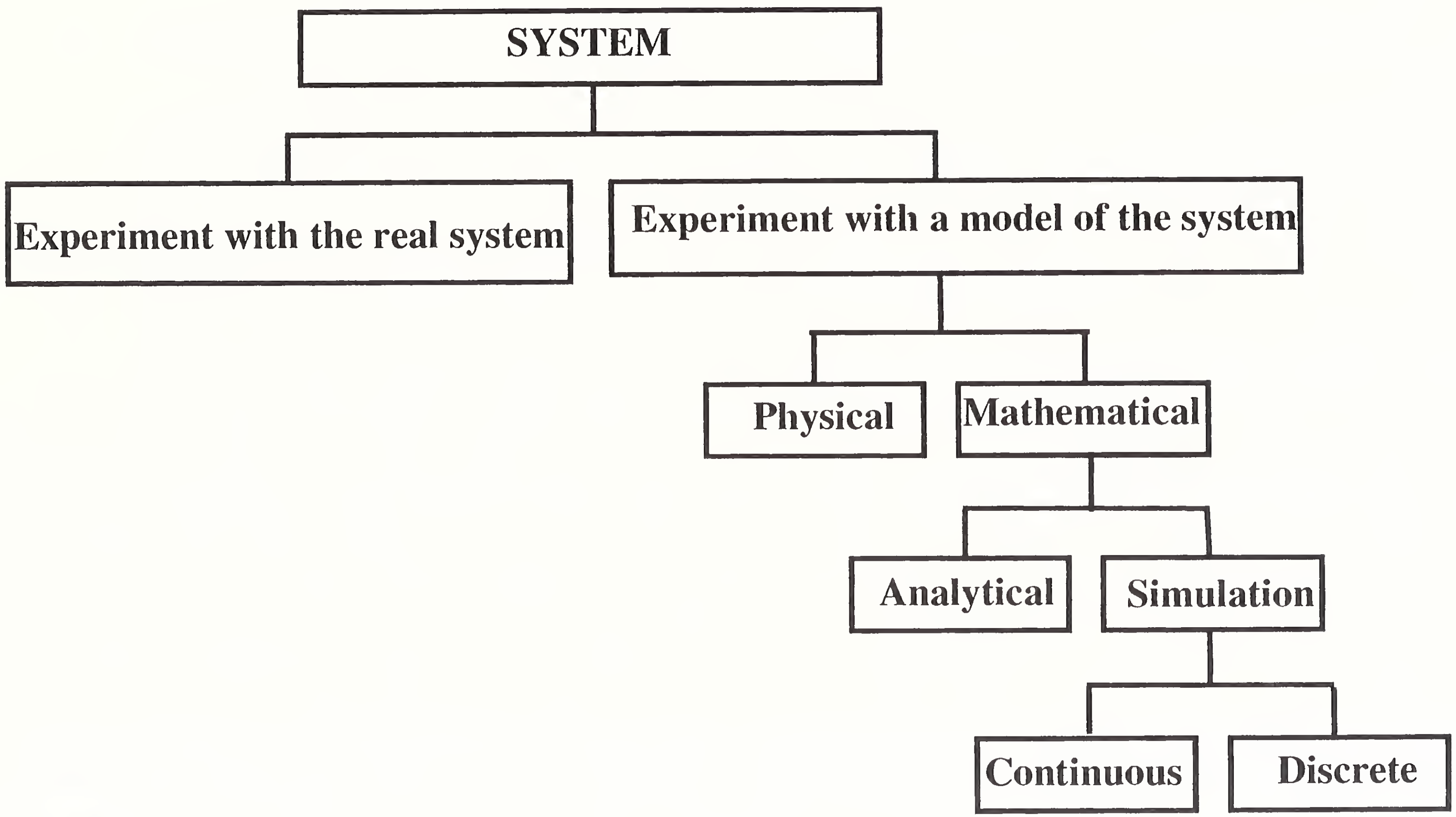
Discrete vs. Continuous Simulation

- Discrete Event Simulation
  - The state of the system changes when an event occurs (at discrete points in time)
- Continuous Simulation
  - The state of the system changes continuously with respect to time (differential equations provide the relationships for the rates of change)

Process Simulation

- Activity-centered view vs. Object-centered view
- Types of process simulation
  - Discrete part manufacturing
  - Continuous process manufacturing
  - Military logistics
  - Battlefield
  - Software/Agent behavior
  - Computer network processes
  - Business processes (Tumay '96)
    - Project-based
    - Production-based
    - Distribution-based
    - Customer service-based

Simulation - A Controlled Experiment



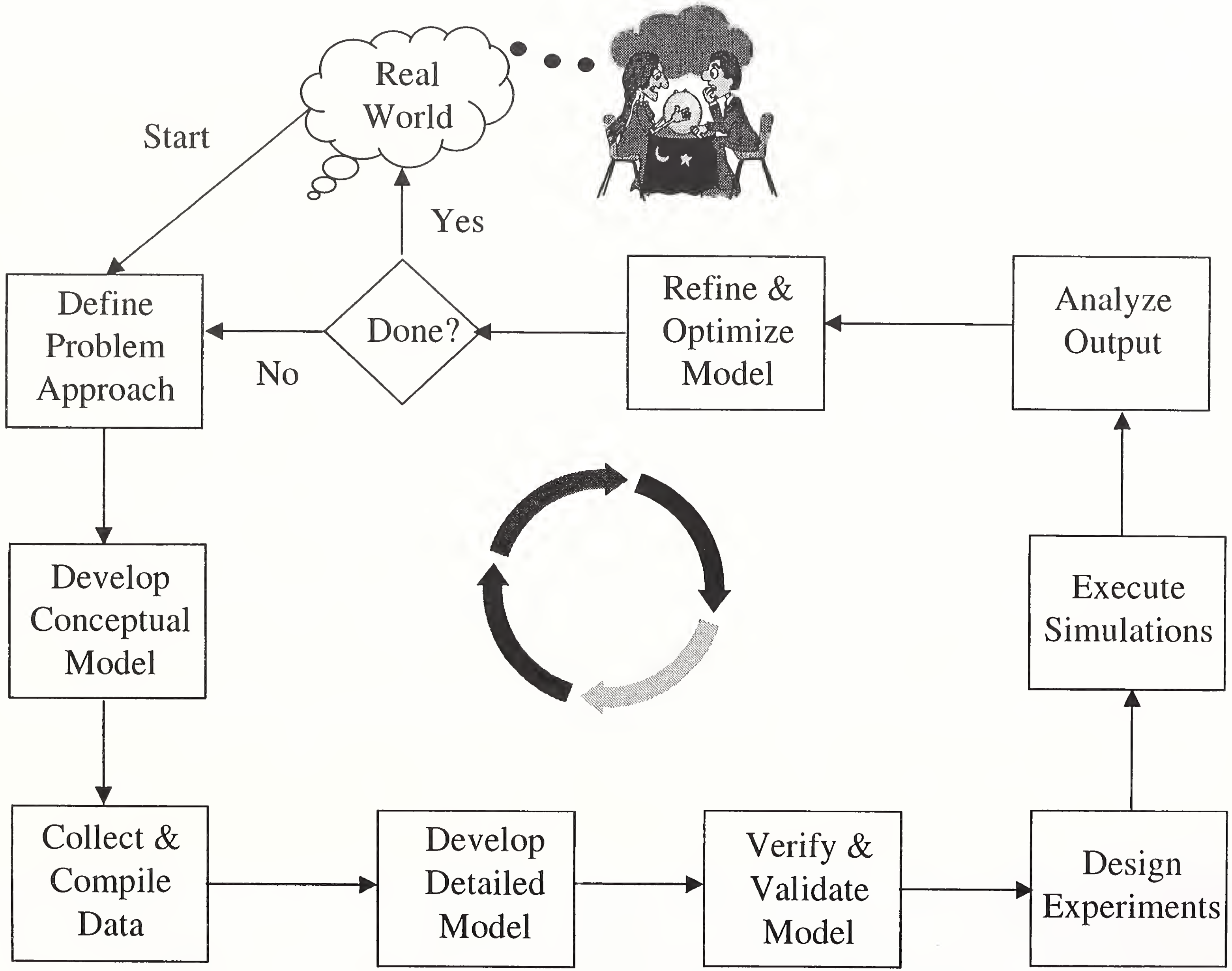
When is Simulation Appropriate?

- Significant randomness in the system
- Contention for shared resources
- Significant system complexity
- Design of new systems with little data

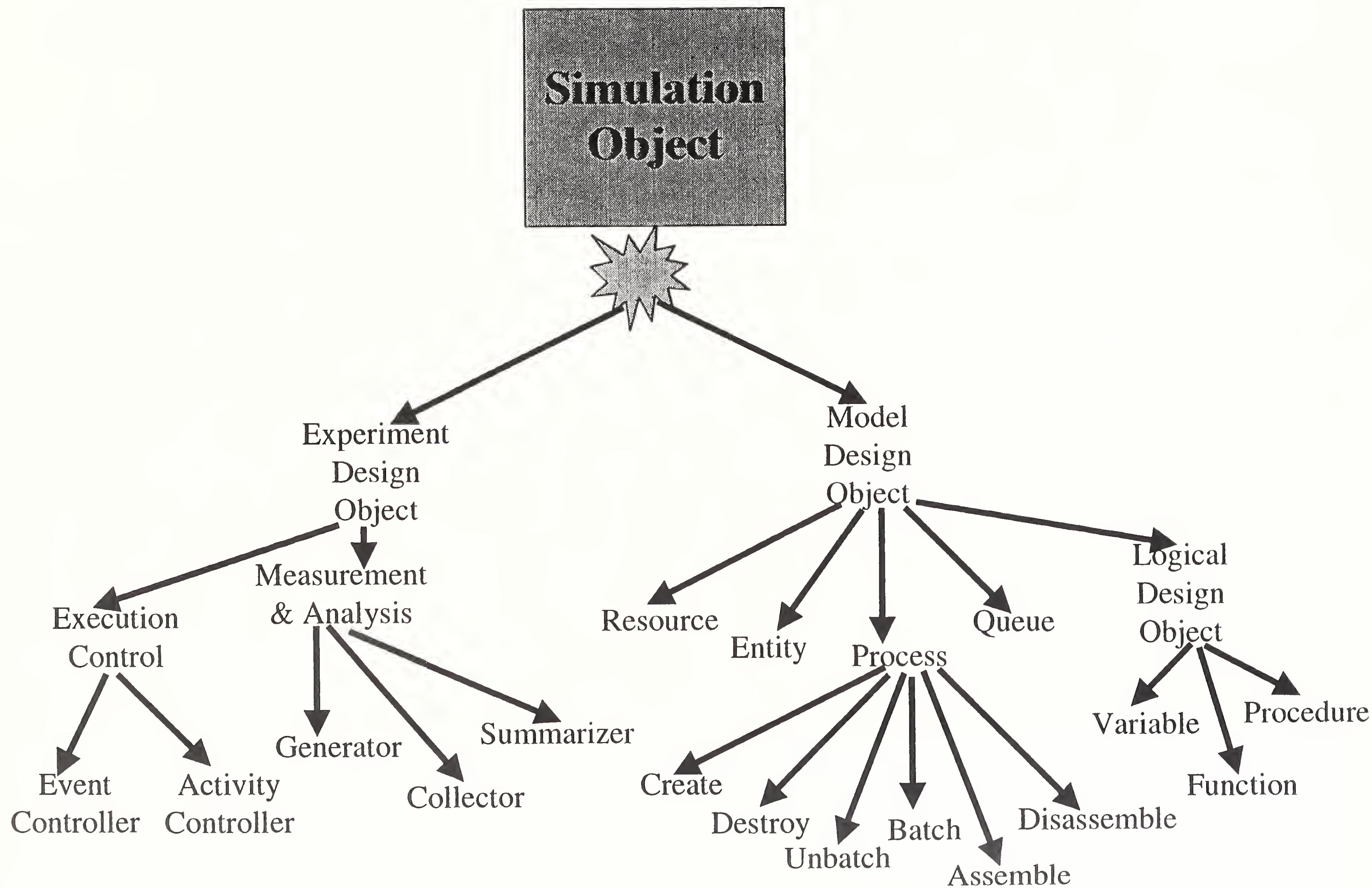
What is Simulation Used For?

- Understanding the behavior of complex systems
- Designing new systems
- Diagnosing problems with existing systems
- Evaluating the effect of decision alternatives on a system

The Simulation Modeling Process

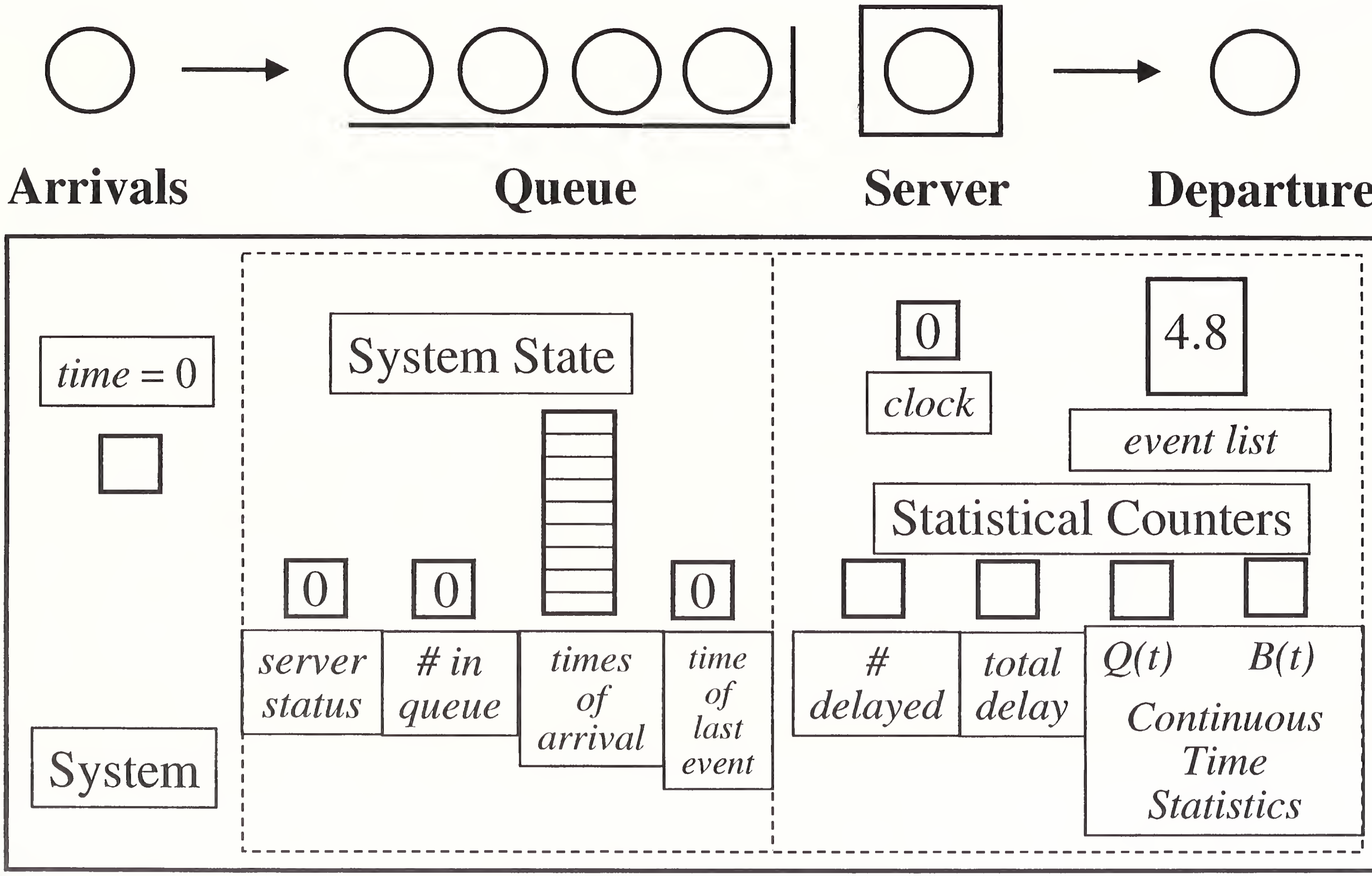


Partial Taxonomy of Simulation Concepts



An Exercise in Book-Keeping

An Exercise in Book-Keeping



Advantages and Disadvantages of Simulation

- Real world systems are too complex for current analytical techniques
- Estimate performance of existing systems
- Experiment with proposed designs
- Complete control over experimental conditions
- Time compression

- It's a sampling experiment
- Tough to validate
- Analysis can become difficult
- Often creates a tendency to place greater confidence in the results than is justified

Simulation Applications

- Manufacturing
- Queuing
- Communication networks
- Capacity analysis
- BPR
- Consumer services
- Scheduling
- Logistics
- Control systems analysis and design
- Bottleneck analysis
- Cost analysis
- Decision support
- Hospital operation
- Traffic analysis

Technical Challenges and Gaps

- Need to integrate work from multiple Modeling and Simulation communities
  - Industry and research
  - Types of simulation- distributed simulation (HLA), discrete simulation, continuous simulation, software simulation, hardware simulation
  - Types of domains - discrete manufacturing, continuous manufacturing battlefield, logistics, business systems, space, project management, agent systems
- Need for standards
  - HLA community are developing protocols
    - address high level interoperation needs
  - Need for bona-fide knowledge sharing mechanisms
    - a PSL for process simulation

Process Simulation Tool Demonstration

Introduction to Activity Based Management and Activity Based Costing

- ABM Concepts
- Motivations for ABC
- ABC Method
- ABC Modeling Issues
- Demonstration

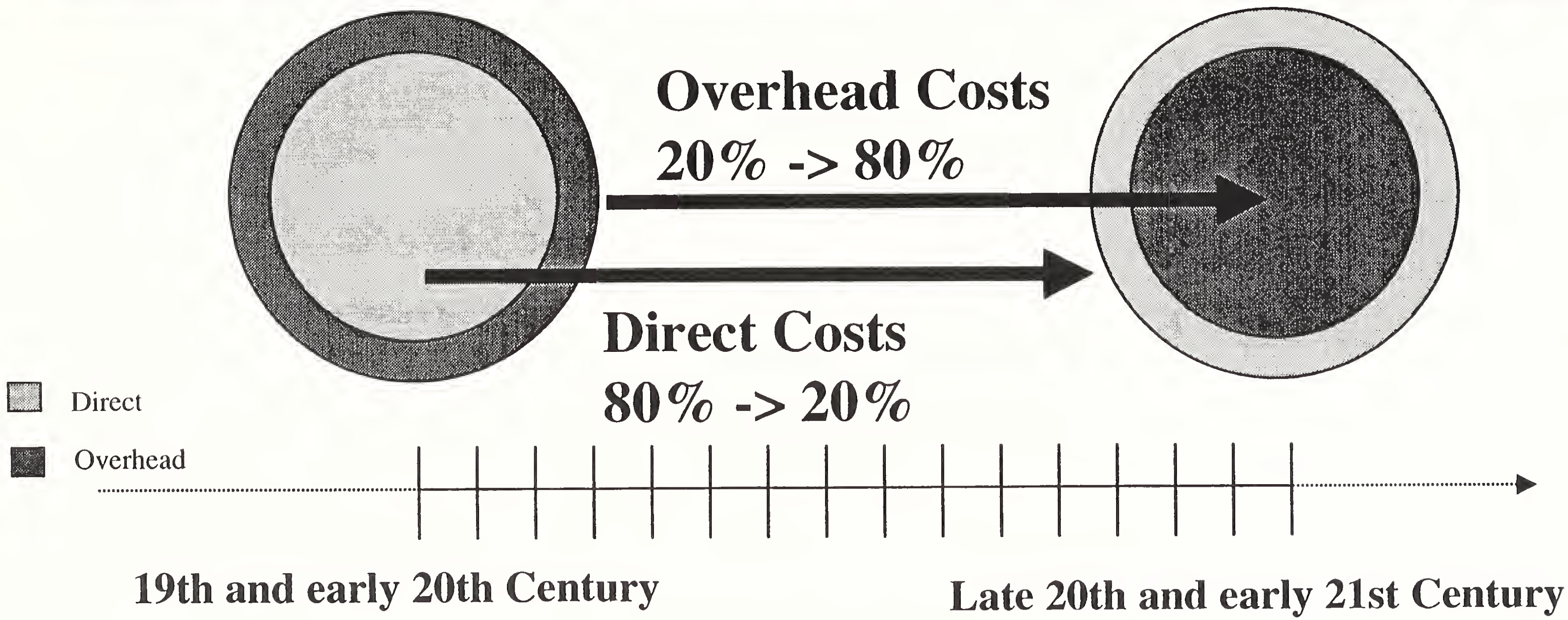
ABM Concepts

- Activity Based Management
  - The use of Activity Based Costing (ABC) for process improvement
  - The use of ABC for management decision support
  - Activity Based Predictive Modeling and Analysis
    - Activity Based Forecasting
    - Activity Based Budgeting

Typical ABM Goals

- Strategic
  - Product mix and pricing
  - Capital budgeting
- Tactical
  - Resource allocation
  - Process improvement

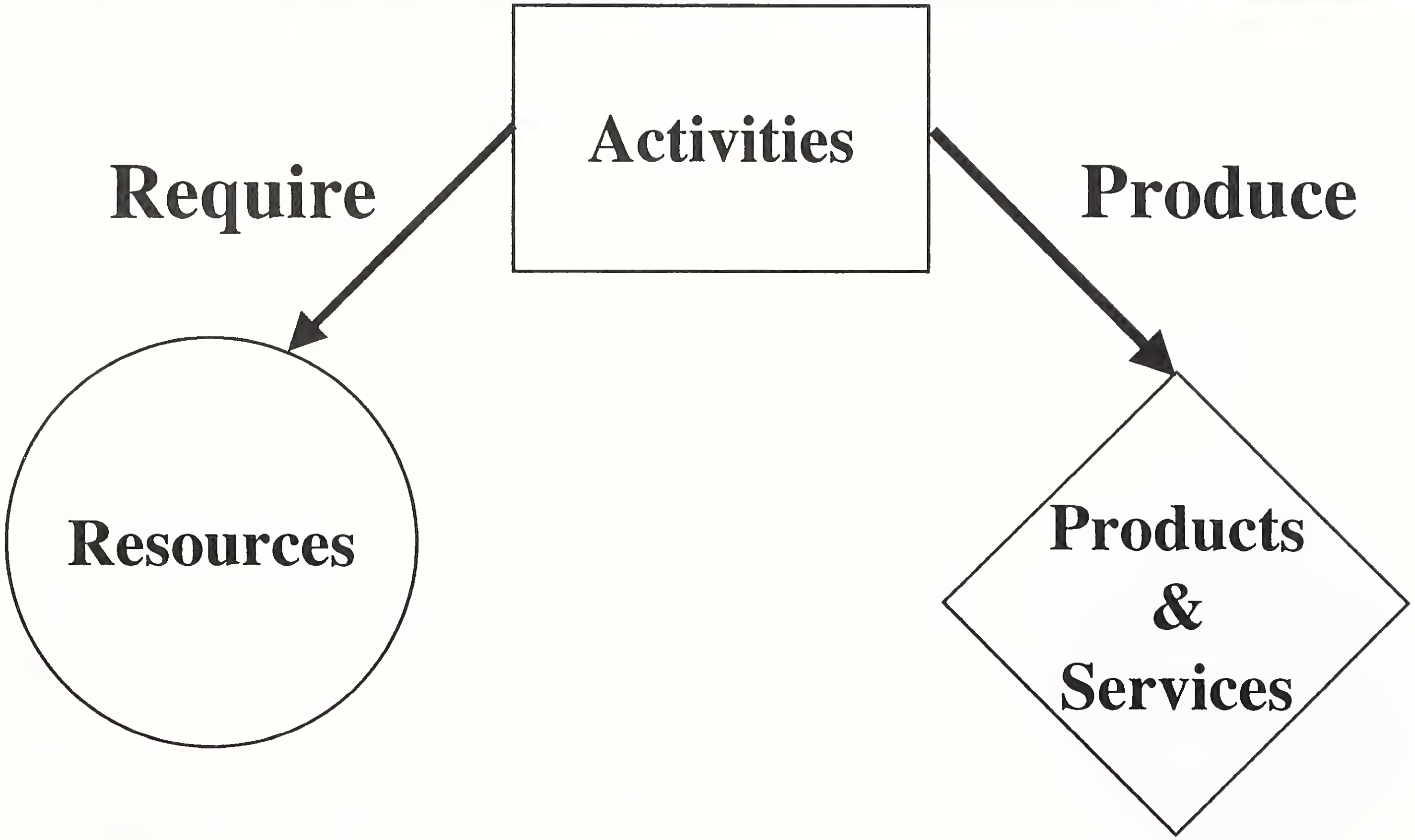
Motivations for ABC



Basis for overhead allocation:

- Traditional costing based on direct hours
- ABC based on consumption of activities by products and services

Advantage of Activity-Centered Costing

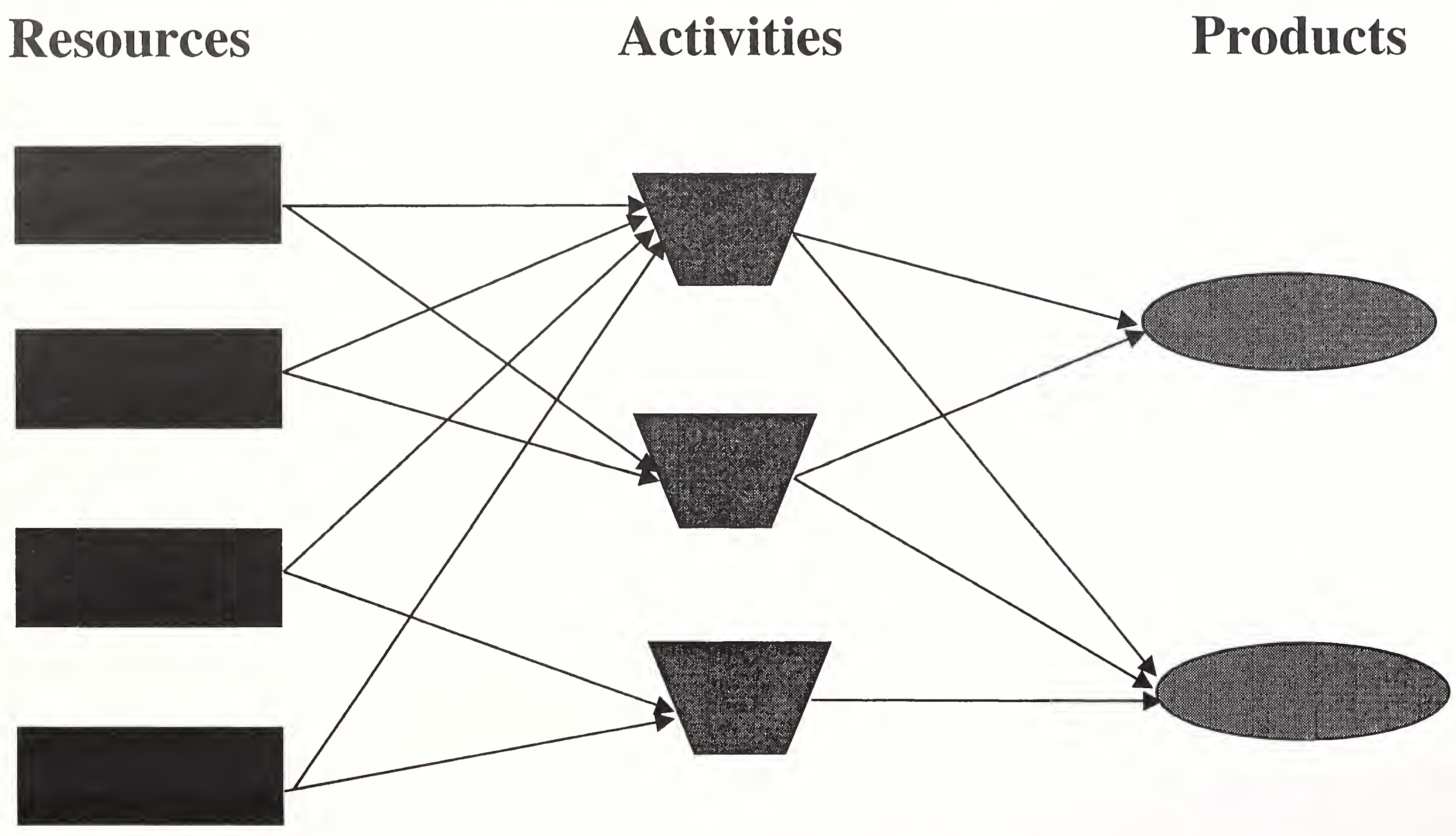


- Helps characterize relationships between value provided to customers and incurred costs

ABC Method

- Four-step process:
  1. Collect costs by type of expense
  2. Allocate from expense pools to resources consumed
  3. Allocate from resource pools to activities
  4. Allocate from activity pools to specific products or services (output pools)

ABC Cost Flow Paths



ABC Terminology

- Pools - aggregations of costs
  - Expense, resource, activity, and product pools
- Allocation/Assignment
  - Relationship that prescribes how one aggregation transforms to another
- Cost Drivers
  - Measurable attributes that causes costs
  - Measurable attributes that provide a (rational) basis for allocation of costs between pools

Key ABM Issues

- Determining appropriate pool categories
- Determining adequate drivers
  - requires ontological analysis of the domain
- Determining the appropriate level of abstraction
  - Trade-off between analysis cost and decision making benefit
- Integrating ABM systems with operational systems

Typical Cost Analysis Questions

- Operational efficiency questions
  - What are my high cost, non value-adding activities?
- Sensitivity questions
  - What activity costs must be reduced to reduce the cost of Product Z by 20%
- Strategic questions
  - What is the best product mix for my value add system?
  - What investment opportunities generate the highest pay-off?

ABM Activities

- Set up ABC model and system
- Validate ABC system
- Use and refine ABC system
  - Initial monitoring and decision making
  - Drive non-linear process change
  - Establish ABC based budgets
  - Monitor against budgets
  - Instrument for continuous process improvement

Setting Up for ABC-Cost Model Design

- Define project
  - Purpose, viewpoint, context
- Acquire and structure process descriptions
  - Identify organizational scenarios and reoccurring situation types
  - Identify activities, objects, relationships
  - Classify objects based on role

IDEF Based ABC Analysis

- Classify processes in terms of value-added, primacy, and discretion (IDEF0)
- Establish value stream (IDEF3)
- Decide on pool categories (IDEF5)

Setting Up for ABC-Cost Model Design

- Develop initial pool categories
  - Expense, Resource, Activity, Product/Service
- Identify/Design cost drivers
  - Rules with formulae and measurable attributes to map from one pool to another
- Introduce intermediate pools where needed
  - When you can't find rules or formulae or factors
- Verify completeness & consistency
  - Does the model work on test data

Model Validation - Comparing a model to real world

- Validation mechanisms
  - User-centered validation
    - Invoke allocations
    - Consolidate
    - Interpret
    - Present to users
    - Collect actual data for comparison
    - Compare model predictions to actuals
  - Simulation-based validation
    - Compare simulation analysis results with ABC results

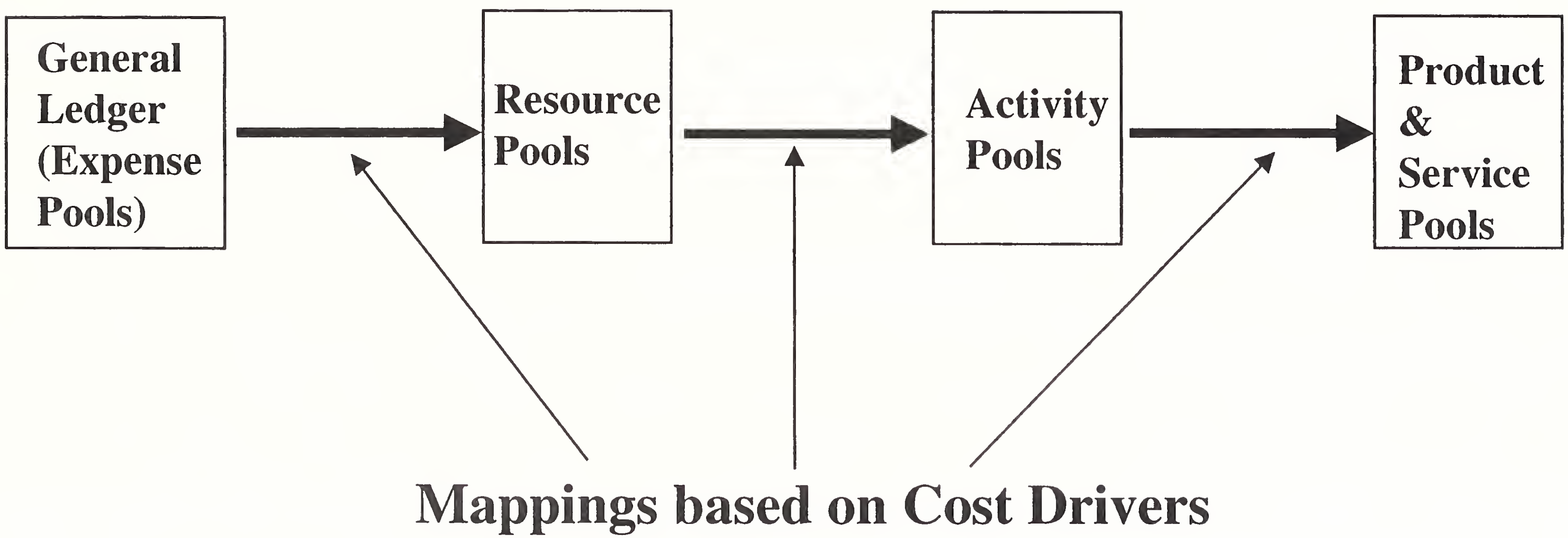
Cost Model Use and Refinement

- Integrate ABC model with accounting system
- Train managers
- Perform analysis in “real” use situation
  - Collect expense data
  - Invoke ABC model
  - Interpret results, make decisions
  - Review decisions
- Refine ABC model

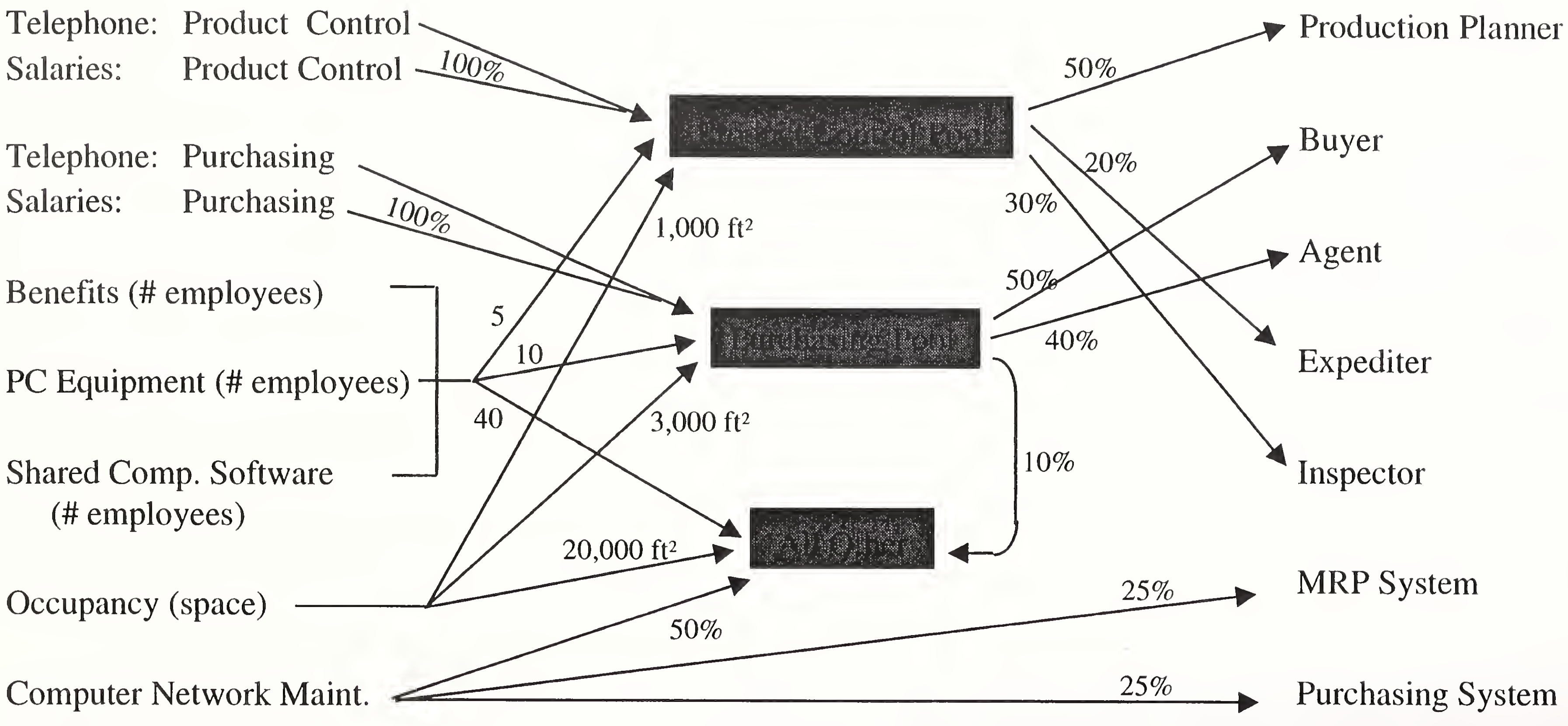
Context of ABM Usage

- Typical initial uses
  - Process evaluation
  - Improvement opportunities
  - Process / system change justification
- Sophisticated uses
  - Replace current cost reporting systems
  - Activity based budgeting
  - Continuous process improvement

Multi-Stage ABC Allocation Process

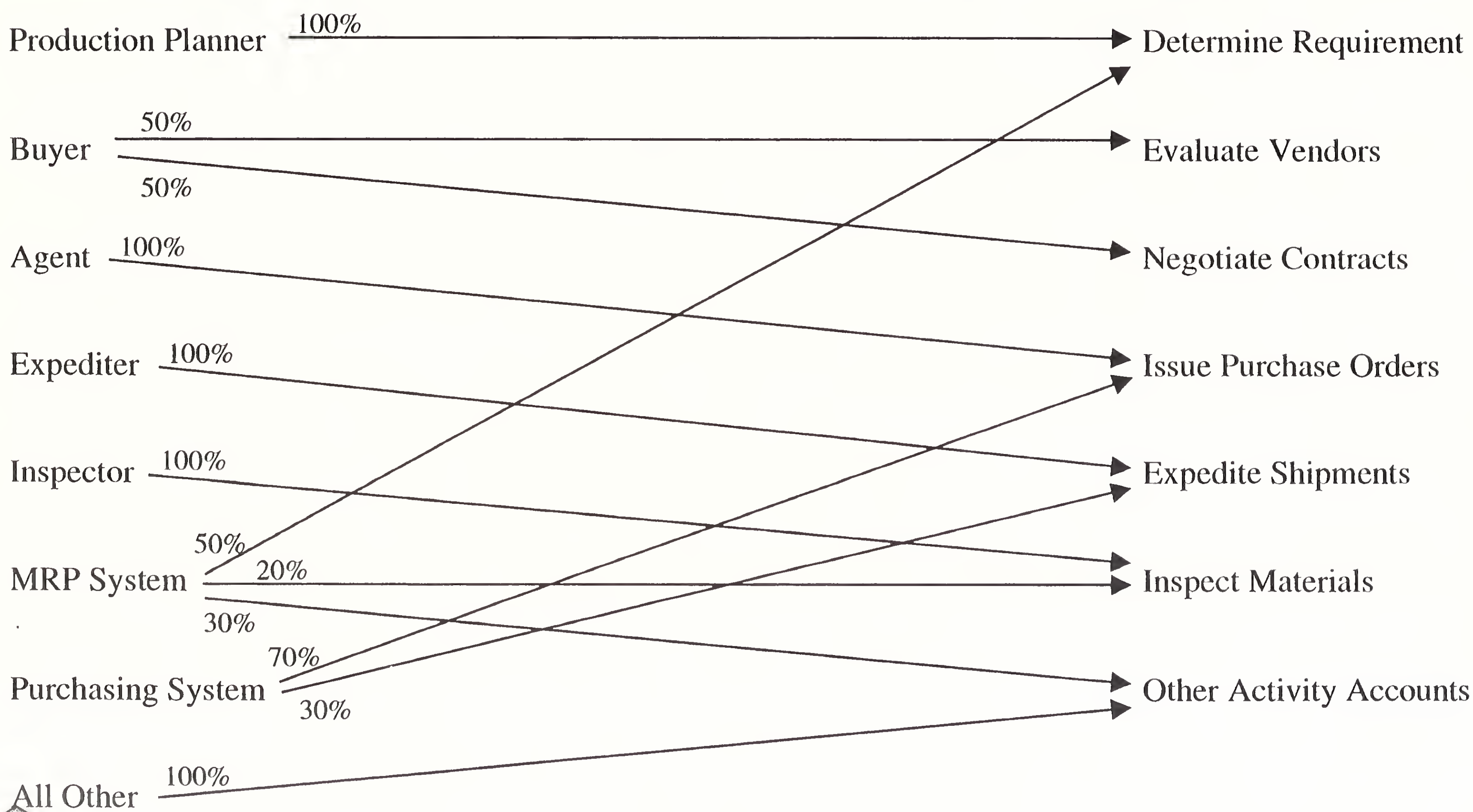


General Ledger Information	Intermediate Resource Accounts	Resources Based on Activity Roles

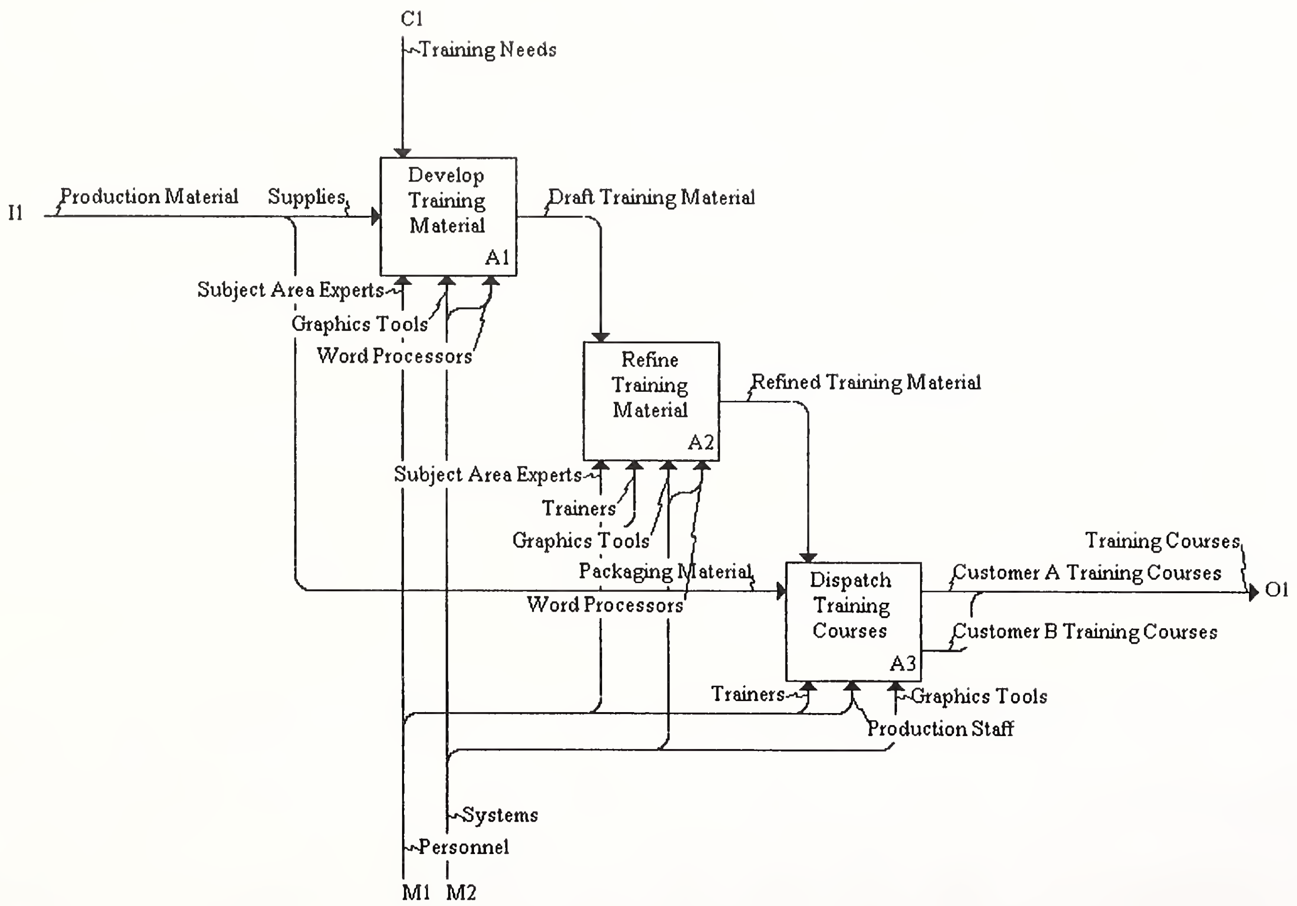


Resources Based on Activity Roles

Activities



Example: Activity Modeling



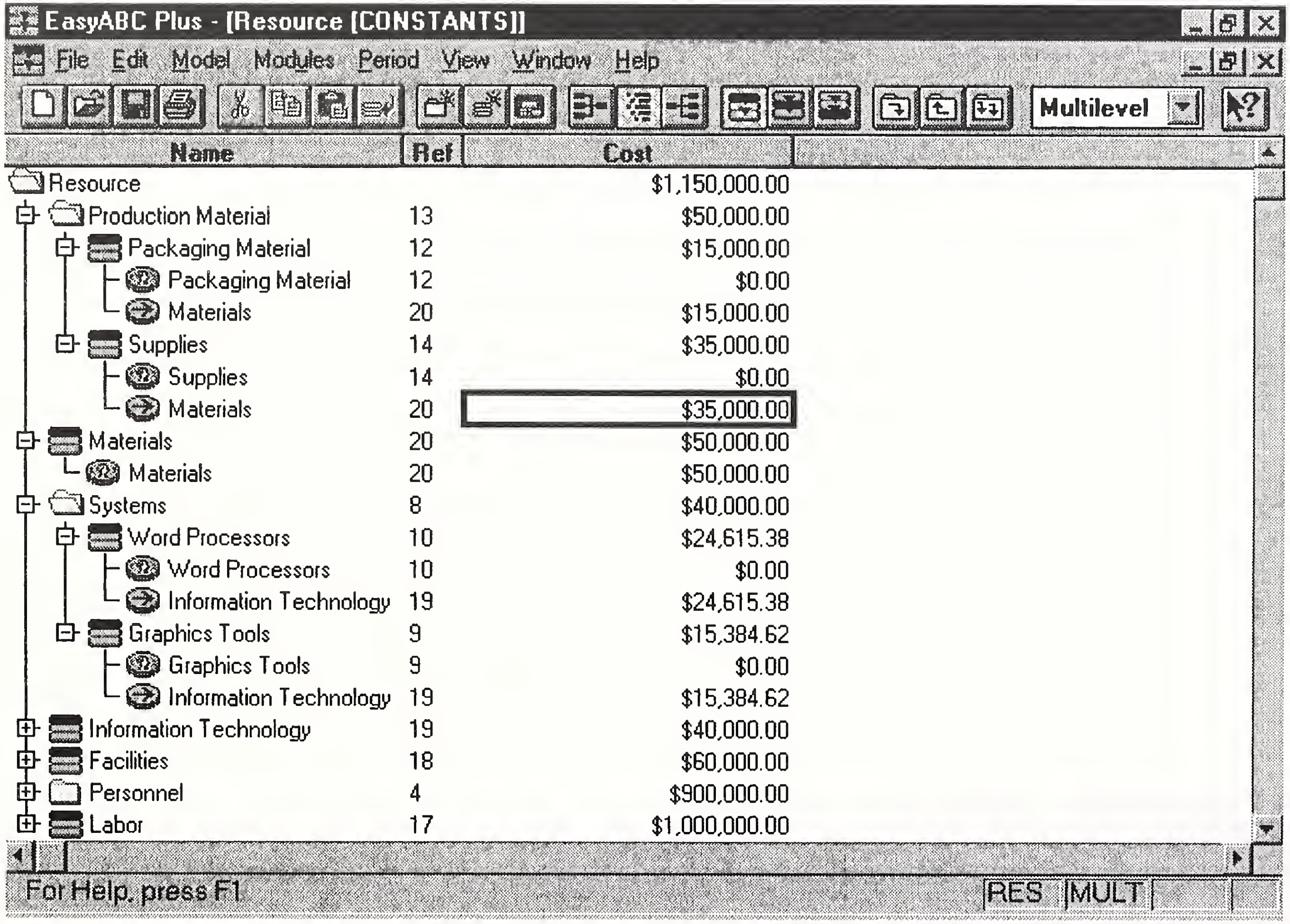
Example: ABC Cost Model Design

Legend:

U = Unspecified
L = General Ledger
R = Resources
A = Activities
CO = Cost Objects
D = Drivers

Sources	Destinations	R: Graphics Tools	R: Packaging Material	R: Personnel	R: Production Material	R: Production Staff	R: Subject Area Experts	R: Supplies
L: Facilities	Area							
L: Information Technology	Number of Co..	(5.0) 38.5%						
L: Labor	PERCENTAGE					20.0%	40.0%	
L: Materials	PERCENTAGE		30.0%					70.0%
R: Graphics Tools	PERCENTAGE							
R: Packaging Material	EVENLY ASSIG..							
R: Personnel								
R: Production Material								
R: Production Staff	EVENLY ASSIG..							
R: Subject Area Experts	PERCENTAGE							
R: Supplies	EVENLY ASSIG..							
R: Systems								
R: Trainers	PERCENTAGE							
R: Training Needs								
R: Word Processors	PERCENTAGE							
A: Develop Training Mater	EVENLY ASSIG..							
A: Dispatch Training Cour:	Number Shipped							
A: Produce Training Cours								
A: Refine Training Material	EVENLY ASSIG..							
CO: Customer A Training C								
CO: Customer B Training C								
CO: Draft Training Material								
CO: Refined Training Mate:								
CO: Training Courses								

Example: ABC Analysis



Summary

- Effectiveness of ABM is dependent on the quality of the ABC model
- IDEF methods facilitate the setup, validation, and use of high quality ABC models in ABM
- Tools are required for ABC modeling in real world settings

ABC Tool Demonstration

Demo Example

- Consider Enterprise XYZ that develops training courses two types of customers A and B
- Analysis questions:
  - What are XYZ's high-cost, non-value adding activities?
  - What strategies should XYZ pursue to realize a 20% reduction in the price of Customer B training course?

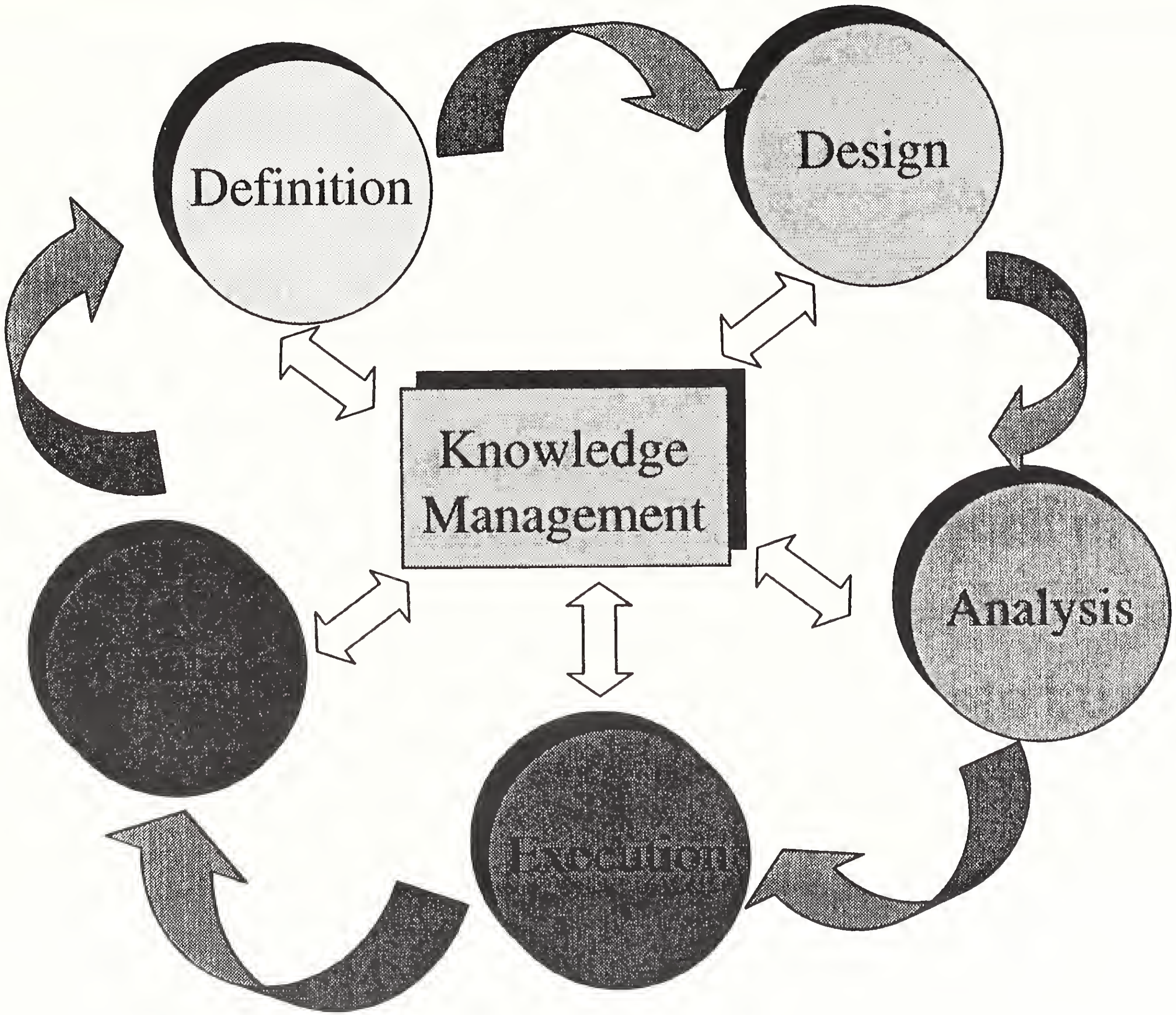
Methods and Tools for Process Knowledge Representation and Acquisition

Christopher Menzel
Knowledge Based Systems, Inc.
cmenzel@kbsi.com
Richard Mayer
Knowledge Based Systems, Inc.
rmayer@kbsi.com
www.kbsi.com

Outline

- Motivations
- Foundations for process knowledge representation
- IDEF3 process description capture method
- Process knowledge capture tool demonstration

Process Technology - A Life Cycle Perspective



Why Process Knowledge Acquisition & Representation?

- Automated process management pre-supposes the existence of stored, computer-interpretable process knowledge
- Process knowledge currently largely resides in non computer processable forms
  - human experts, documents, databases, videos
- Past knowledge acquisition efforts have failed to provide robust methods and tools for large scale process knowledge capture
- Lack of robust mechanisms for process knowledge representation and sharing
  - currently an area of active research

Foundations for Process Knowledge Representation

What is an Enterprise Model?

- A *representation* of some aspect or element of an enterprise
  - The structure of a database
  - A software design
  - A common business activity
  - A manufacturing process
  - A business plan

What is a Representation?

- Two elements
  - A Language
    - Graphical
    - Textual (informal)
    - Formal
  - Semantics
    - An account of what representations in the language *mean*.

Two Common Problems with Modeling Languages

- The Syntactic Problem
  - No explicit grammatical rules
    - No specification of syntactic rules, hence no definite notion of a well-formed model.
- The Semantic Problem
  - No explicit, formal semantics
    - No formal specification of the meanings of a languages representations.

Consequences of these Problems

- Limited ability to reuse models
- Limited ability to share models
- Limited ability to integrate models
- No sound basis for model creation software
- No basis for automated reasoning on the information in and across models

The Problem in a Nutshell

- **Enterprise modeling is currently not a genuine *science***
- **In particular, enterprise modeling has no proper mathematical foundation**
  - Compare calculus before Cauchy/ Riemann

First-order Logic

- The language of mathematics
- Some history
- Virtues
  - It is *completely understood*
  - It has a well-defined, mathematically precise syntax, semantics, and proof theory
  - It is expressively adequate
    - The content of any enterprise model can be expressed in a first-order language

An Argument

- Formal Theories
  - A precise account of some aspect of the world captured in FOL
    - Newtonian mechanics
    - Group theory
- Modeling frameworks are theory-like
  - They are accounts of the world tailored to certain kinds of enterprise information
- Consequently: modeling frameworks too should be formalized in FOL

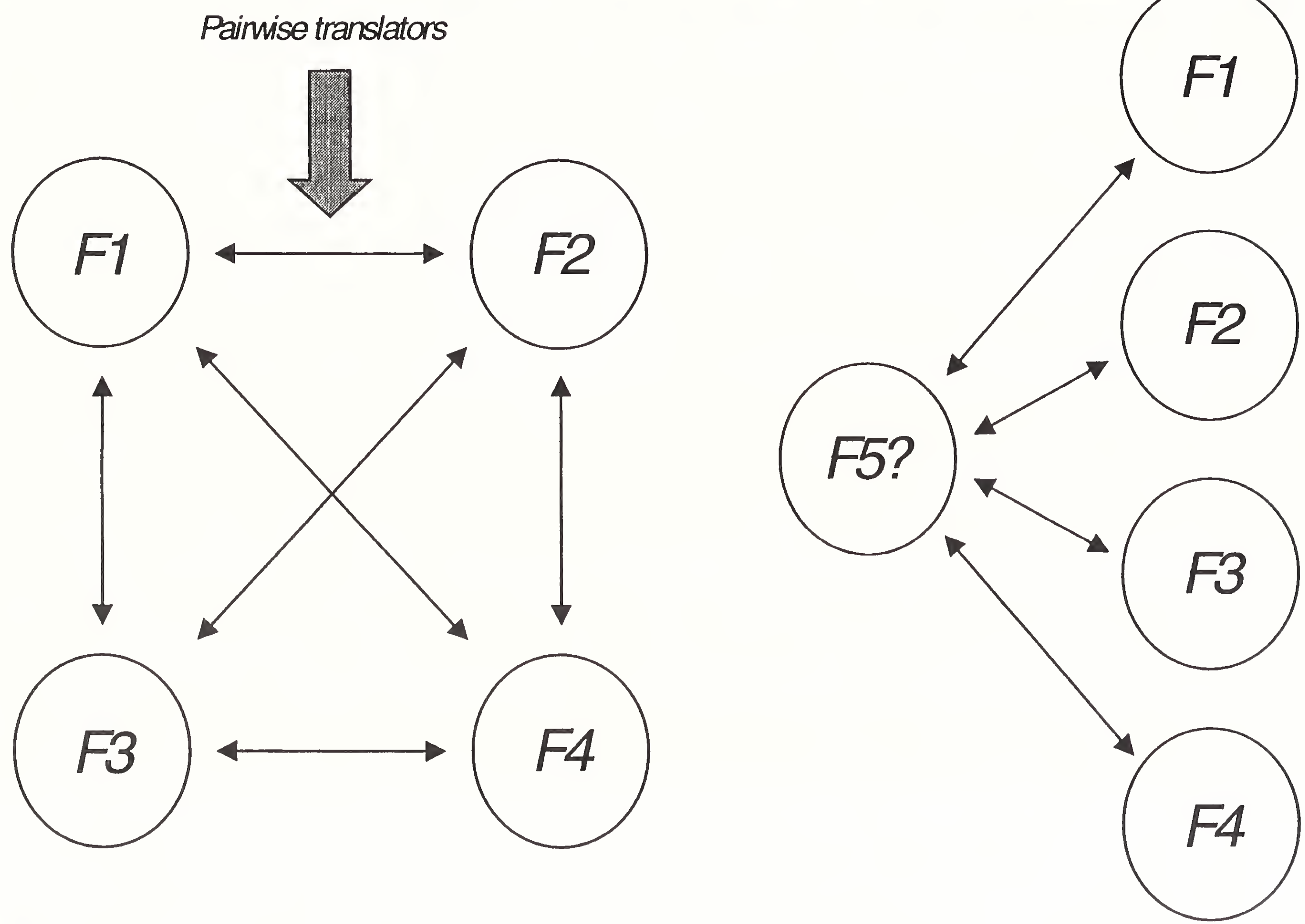
Approach

- Formalize all enterprise modeling frameworks as first-order theories (language + formal semantics + axioms)
  - In particular, define the notion of a model in each modeling theory in first-order terms
- Define formal mappings between the graphical syntax of a modeling language and its first-order counterpart
  - Traditional modeling framework then inherits the virtues of FOL

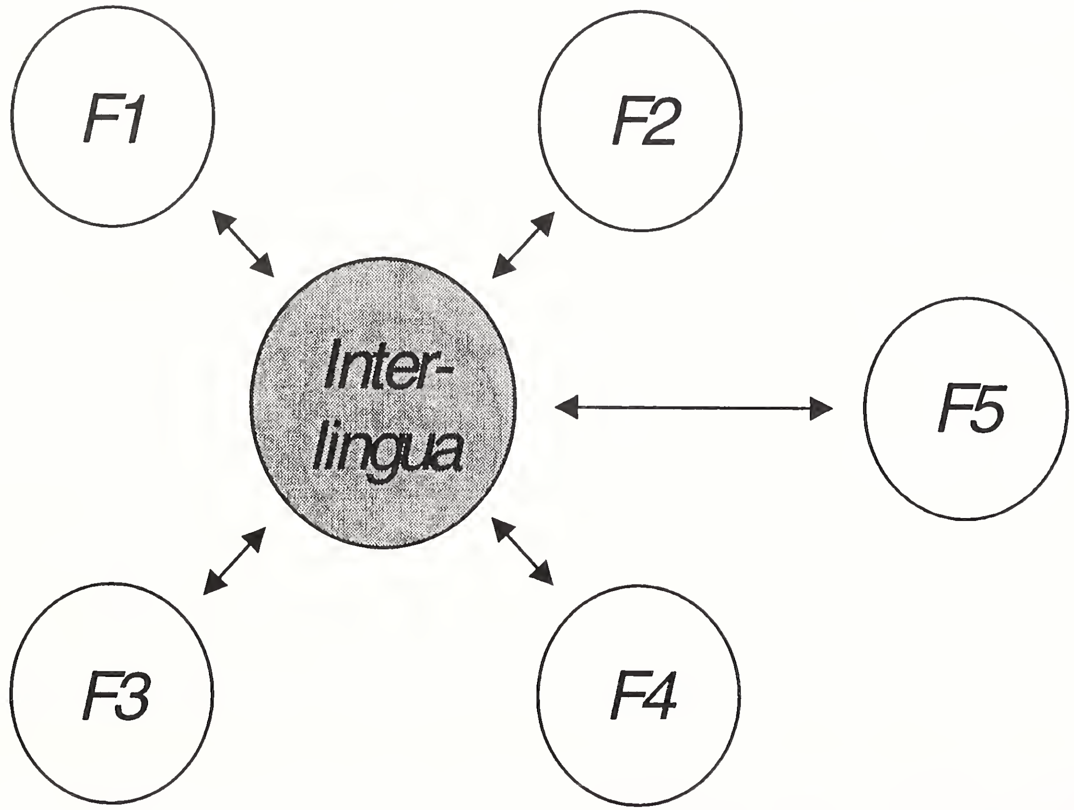
The Implications for Tools

- Tools can be constructed in accordance with formal syntactic and semantic specifications.
- When done right, modelers are shielded (if desired) from the underlying logical machinery.
- But the underlying foundations will yield reusable, shareable, integrable models.

The $O(n^2)$ problem



Interlinguas: $O(n^2)$ to $O(n)$

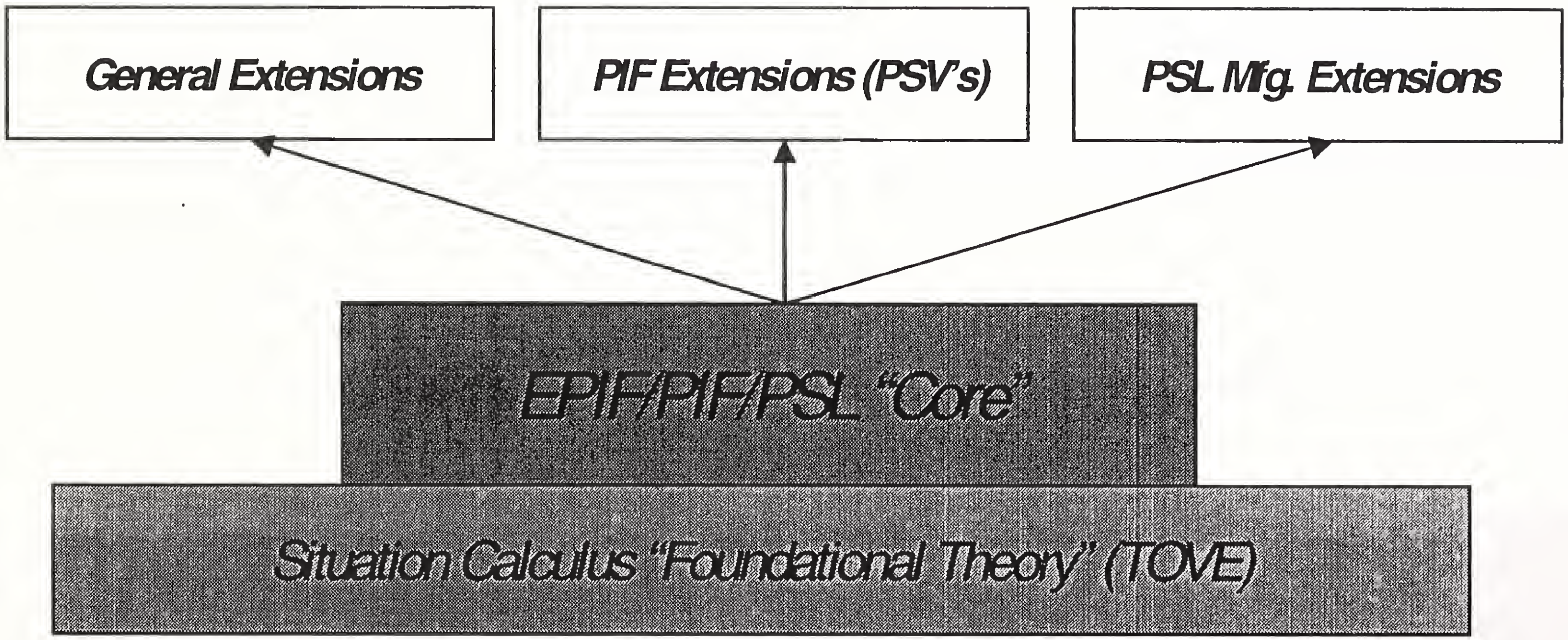


A Cooperative Effort

- TOronto Virtual Enterprise Project (TOVE)
  - Situation calculus as the "foundational theory"
- NIST Process Specification Language (PSL)
- The Process Interchange Format (PIF)
- KBSI "Enhanced" Process Interchange Format (EPIF)
  - Situation theoretic underpinnings

A Cooperative Effort

Representatives from all four efforts are working together in the PIF and PSL projects toward a unified interlingua for process knowledge.



Why Process Representation is Hard

- Not enough to talk about objects and their properties over time
- Dynamic entities (activities, processes) must be treated as first-class citizens
- Processes are *complex*
  - Temporally structured collections of activities
  - Activities comprise objects
  - Objects change their properties over time

Toward an Interlingua for Process Knowledge

- The Core
  - Activities
  - Objects
  - Timepoints
- Extensions (Modules, PSVs)
  - Math (integers, sets, etc.)
  - Durations, clocks, calendars
  - Resources
  - Goals, process intent
  - Etc...

Other Notable Efforts

- ARPI Shared Planning and Activity Representation (SPAR)
- EXPRESS process extension
- CDIF
- Workflow Management Coalition

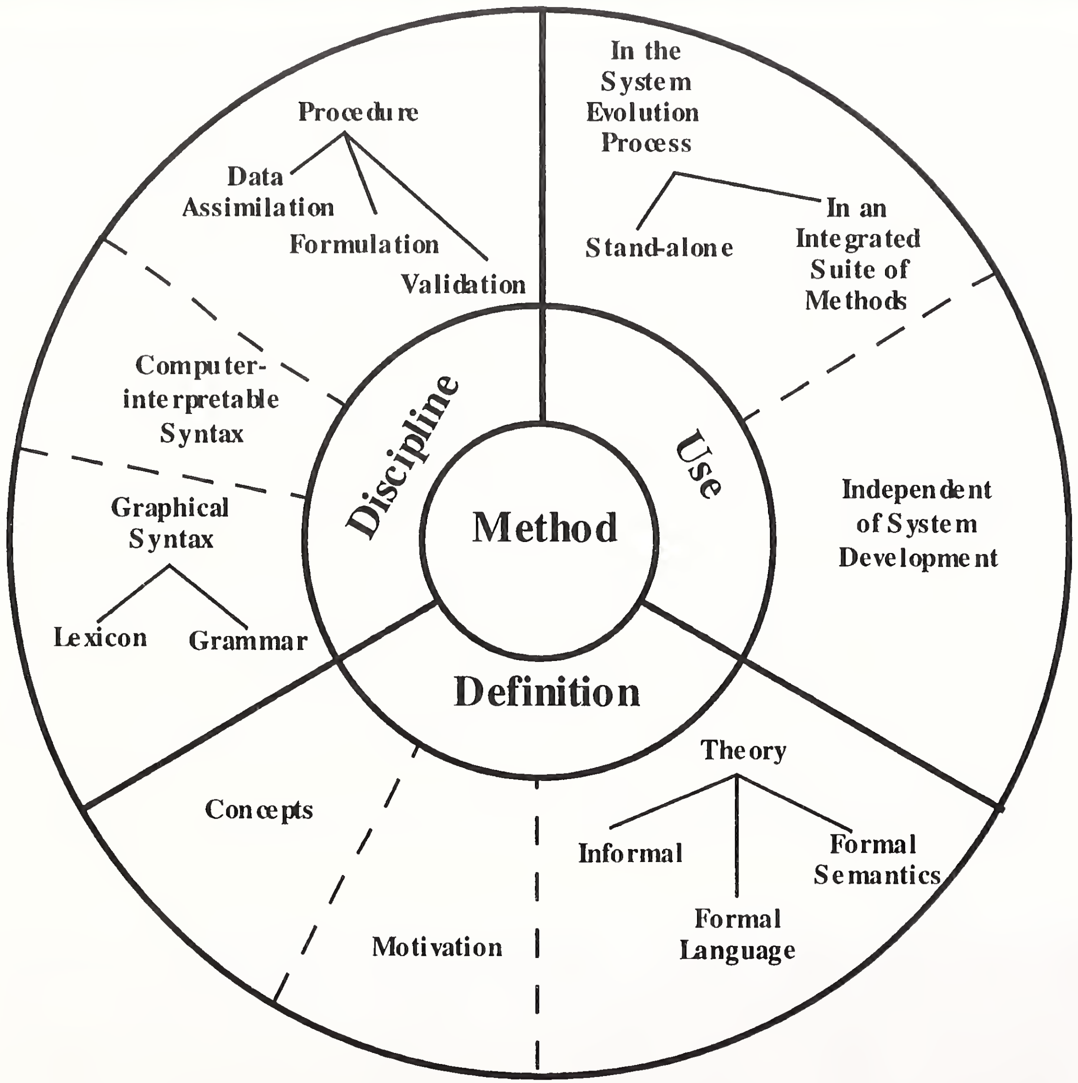
Formal approach enables a precise characterization of the logical connections between different approaches, as well as the formulation of clear rules for accurate knowledge interchange between them.

Process Description Capture Using IDEF3

Background

- Public domain method developed 1991 - 1995 through AF sponsorship
  - two versions, 1992 and 1995
- Large scale use of IDEF3 started with release of first automated IDEF3 tool in 1992
- Increasingly popular method in both the government and the private sector
  - Over 3000 installed tool users

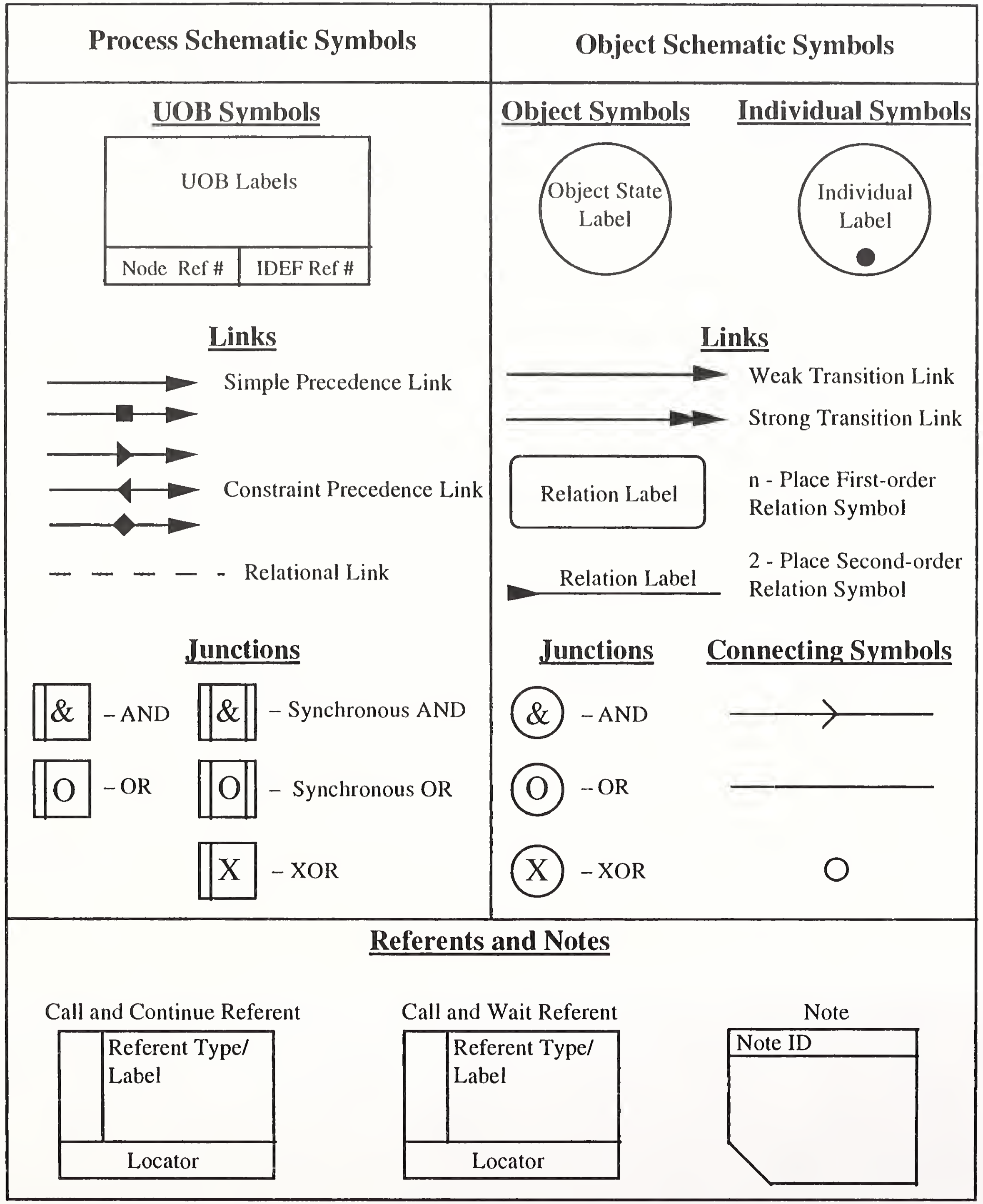
Anatomy of a Method



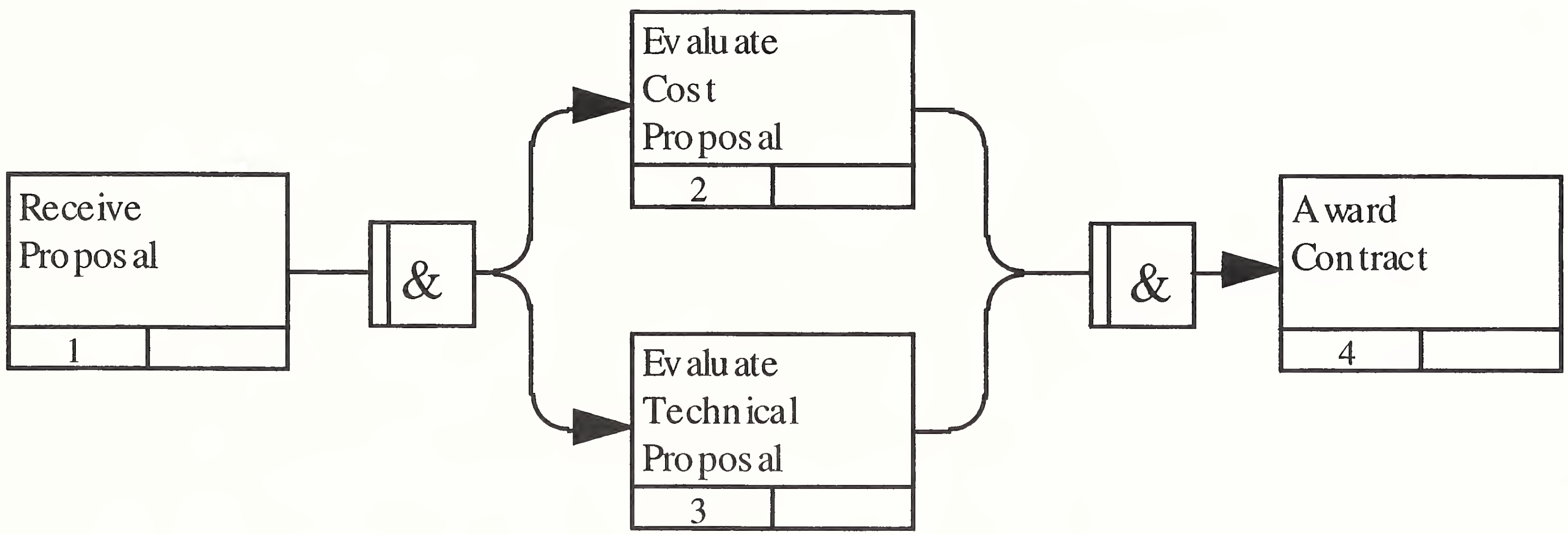
Main Components of IDEF3

- Languages
  - Graphical
    - Process Schematics
    - Object Schematics
  - Textual
    - IDEF3 Elaboration Language
- Procedure: "distillation of best practice"
- Theoretical foundations

IDEF3 Graphical Languages: Lexicon



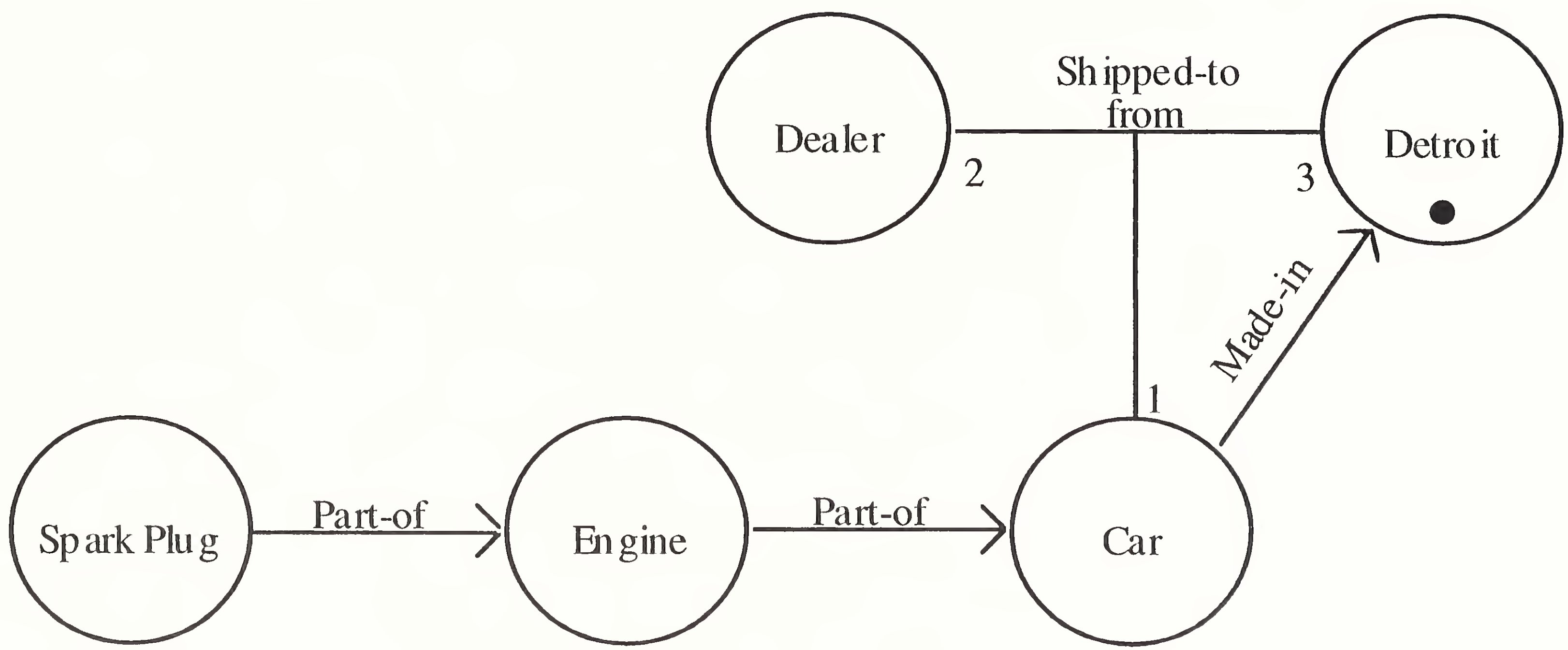
Example Process Schematic



Example Elaboration

- ; Scenario definition
- (I3-Process Example-Process)
- ; UOB definitions
- (I3-UOB Receive-Proposal)
- (I3-UOB Evaluate-Cost-Proposal)
- (I3-UOB Evaluate-Technical-Proposal)
- (I3-UOB Award-Contract)
- ; Inter-process constraints
- (I3-Concurrent-After Receive-Proposal Evaluate-Cost-Proposal Evaluate-Technical-Proposal Example-Process)
- (I3-Concurrent-Before Award-Contract Evaluate-Cost-Proposal Evaluate-Technical-Proposal Example-Process)

Example Object Schematic



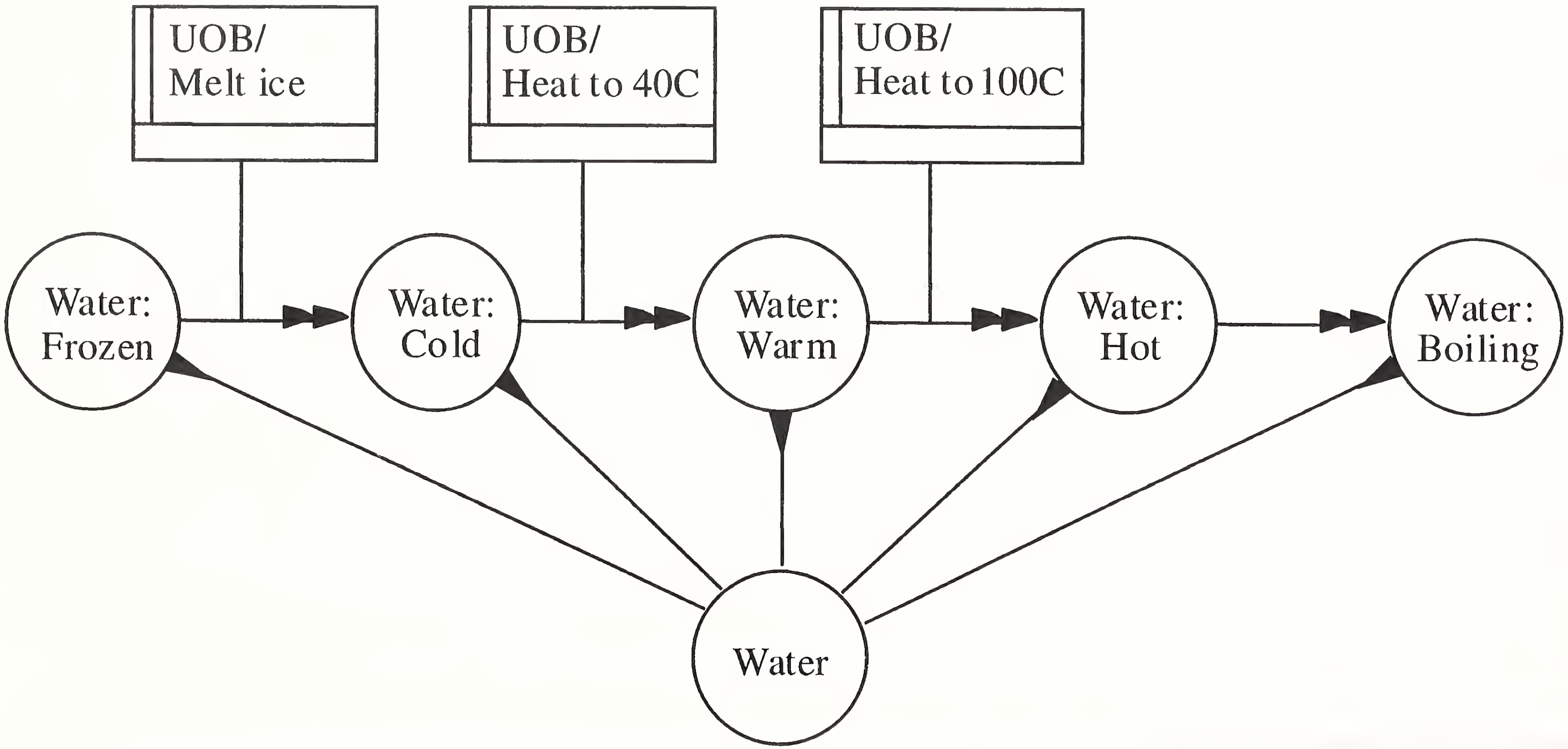
Example Elaboration

- ; Definitions
- (I5-Kind Car)
- (I5-Kind Dealer)
- (I5-Kind Engine)
- (I5-Kind Spark-Plug)
- (I5-Kind City)
- (I5-Individual Detroit)
- (I5-is-of-kind Detroit City)
- (I5-relation Part-of)
- (I5-relation-arity Part-of 2)
- (I5-rel-arg-type Part-of ((Spark-Plug Engine) (Engine Car)))
- (I5-relation Made-in)
- (I5-relation-arity Made-in 2)
- (I5-rel-arg-type Made-in ((Car City)))

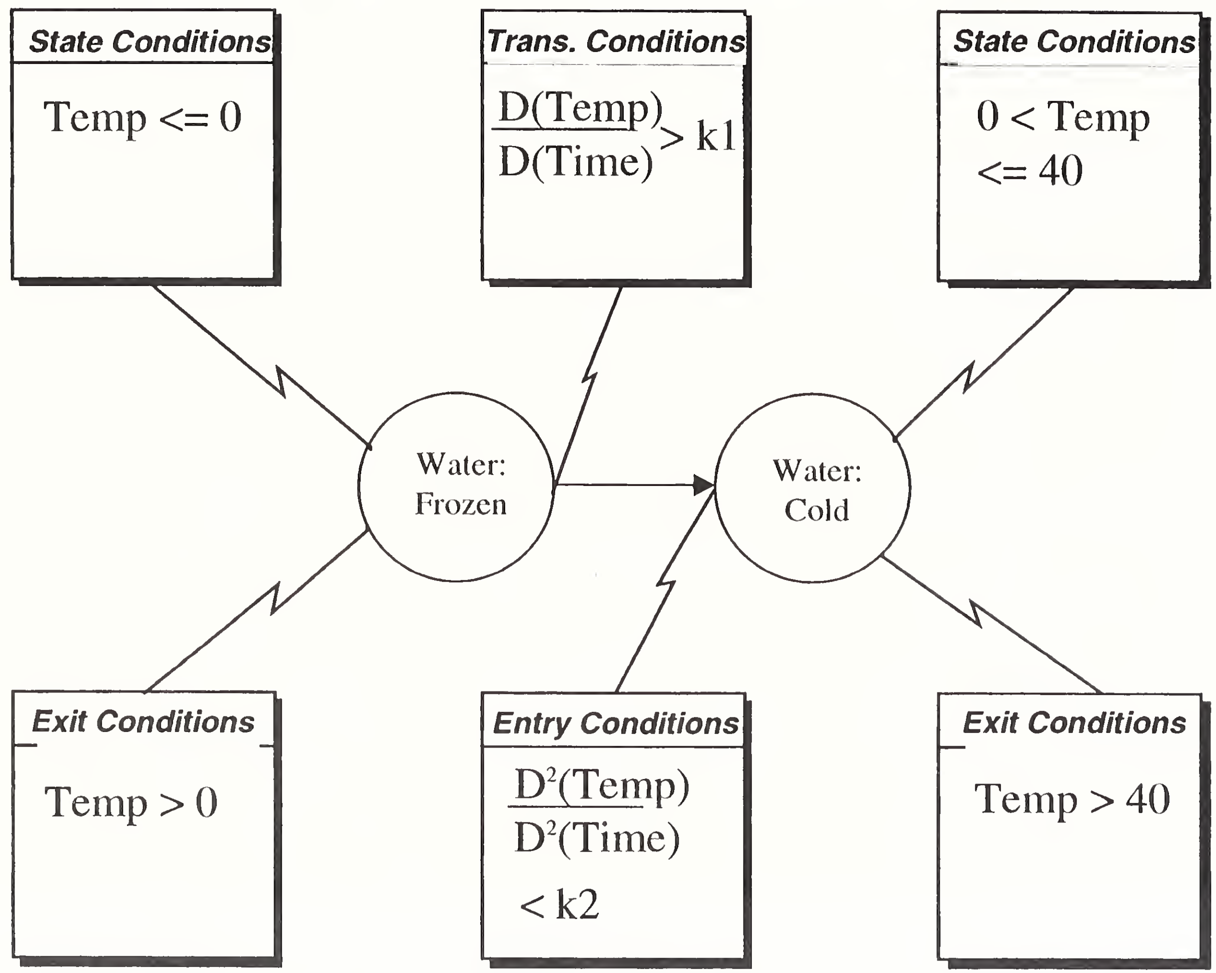
Example Elaboration

- ; Relation specifications
- (forall (?x ?y) (=> (and (Made-in ?x ?y) (I5-is-of-kind ?x Car))
  (= ?y Detroit)))
- (I5-relation Shipped-to-from)
- (I5-relation-arity Shipped-to-from 3)
- (I5-rel-arg-type Shipped-to-from ((Car Dealer City)))
- (forall (?x ?y ?z) (=> (and (Shipped-to-from ?x ?y ?z) (I5-is-of-kind ?x Car)
  (I5-is-of-kind ?y Dealer))
  (= ?z Detroit)))

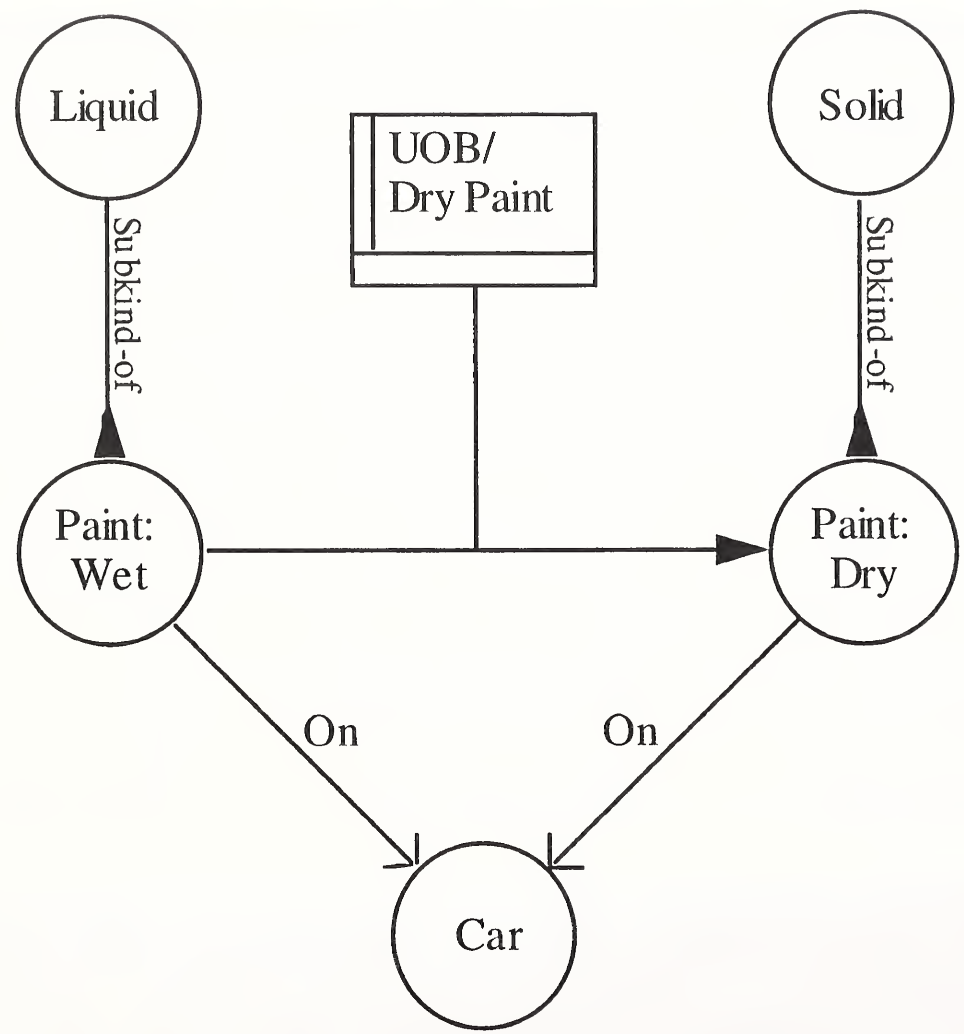
Example Object Schematic: State Transitions



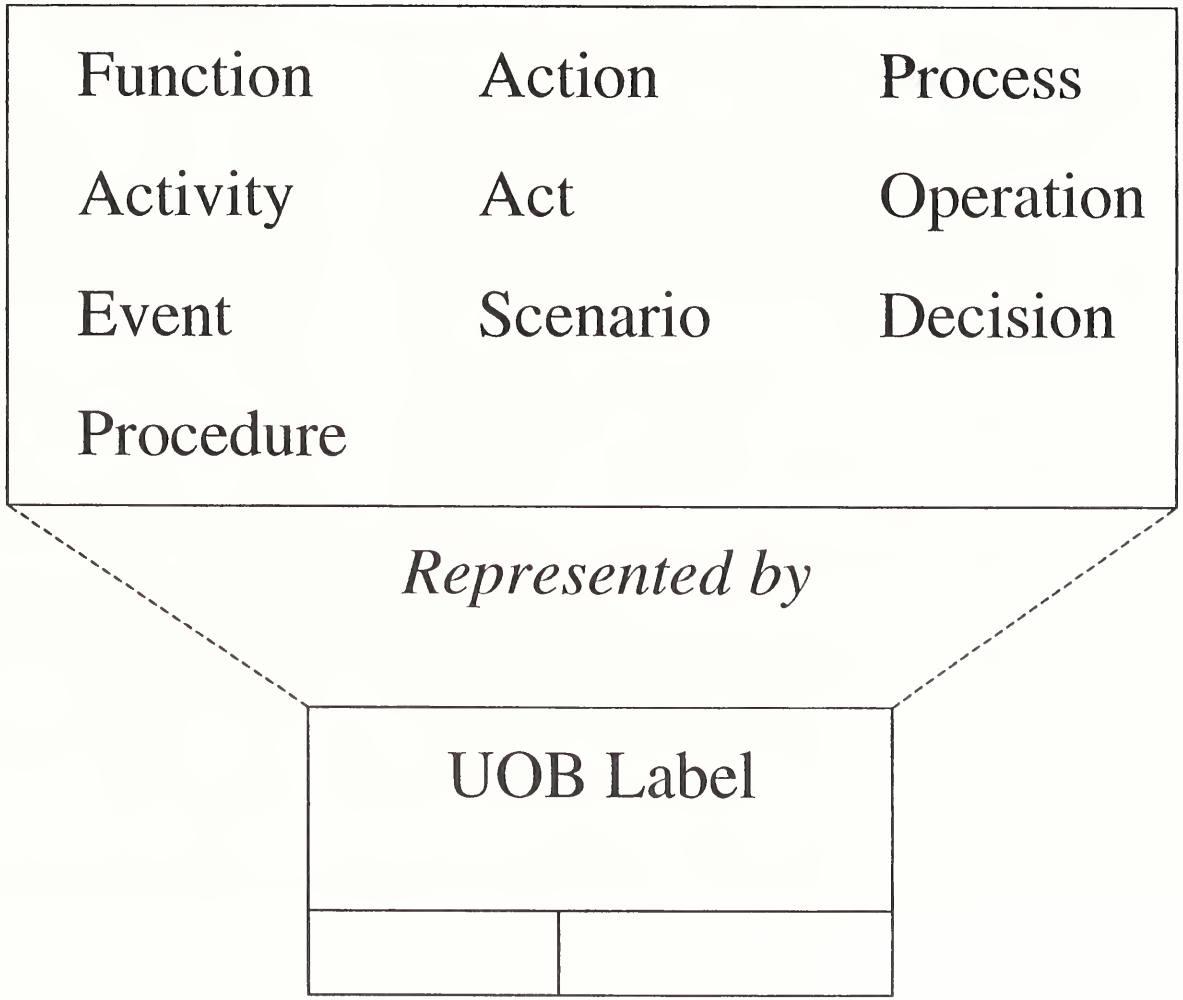
Transition Conditions



Example Object Schematic



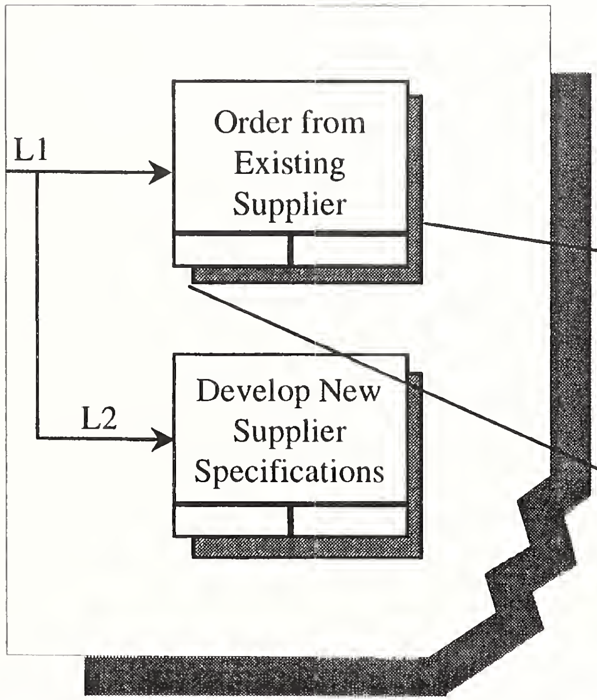
Units of Behavior (UOBs)

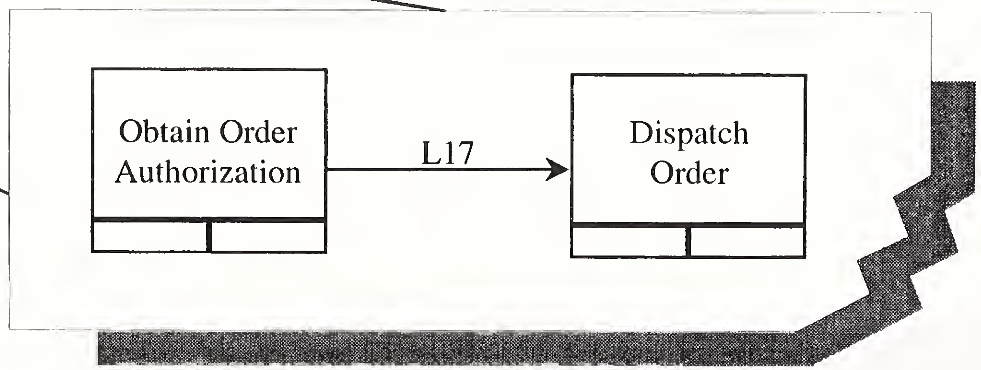


UOBs Decompositions

- Decompositions are more detailed descriptions of UOBs

A UOB can have several decompositions, allowing for the representation of activities from multiple perspectives

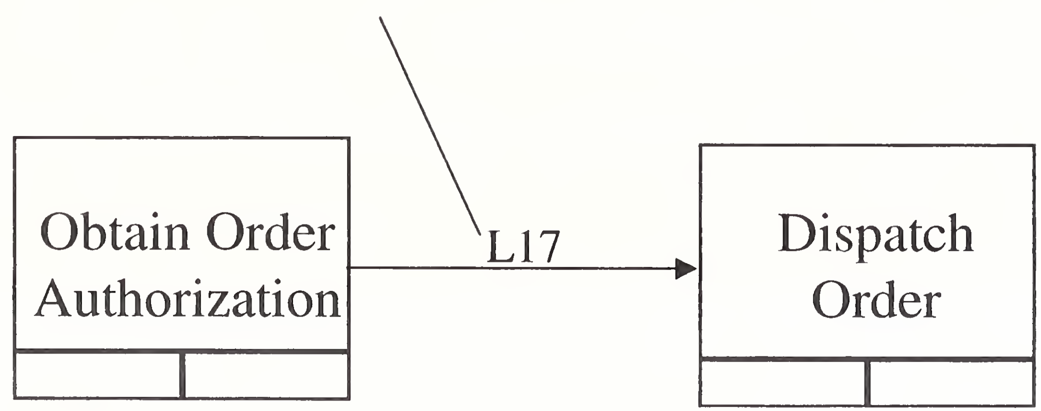




Links

- Links are used to represent different types of relationships between activities

This simple precedence link indicates that the the Dispatch Order activity can start after the Obtain Order Authorization activity has completed



Link Types

- A <u>Simple Precedence</u> link is used to represent a simple temporal precedence relationship between activities

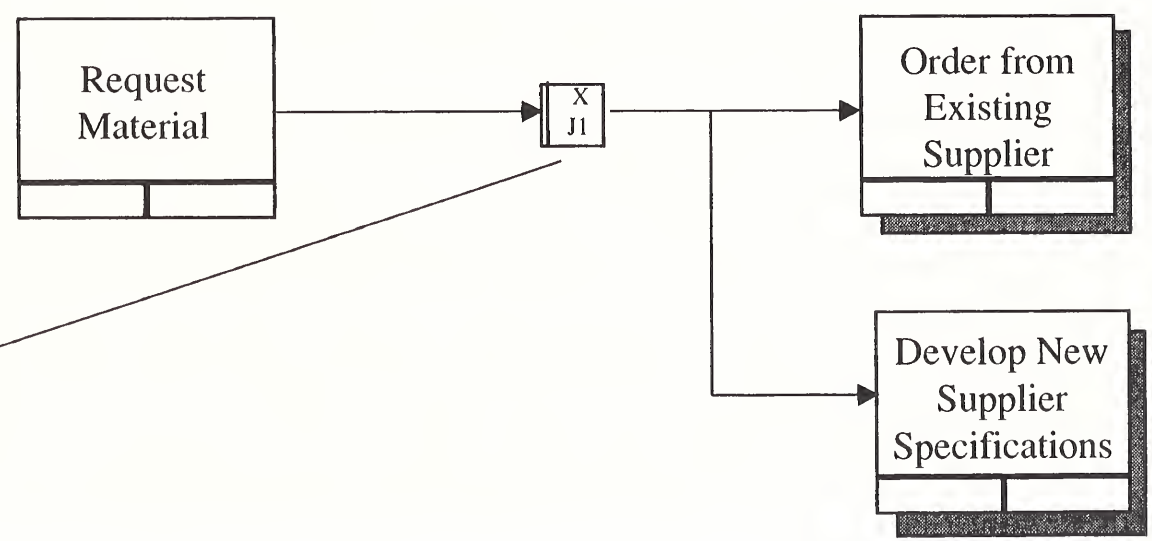
- A <u>Constrained Precedence</u> link is used to represent a constrained precedence relationship between activities

- A <u>Dashed</u> link is used to represent a user-defined relationship between activities

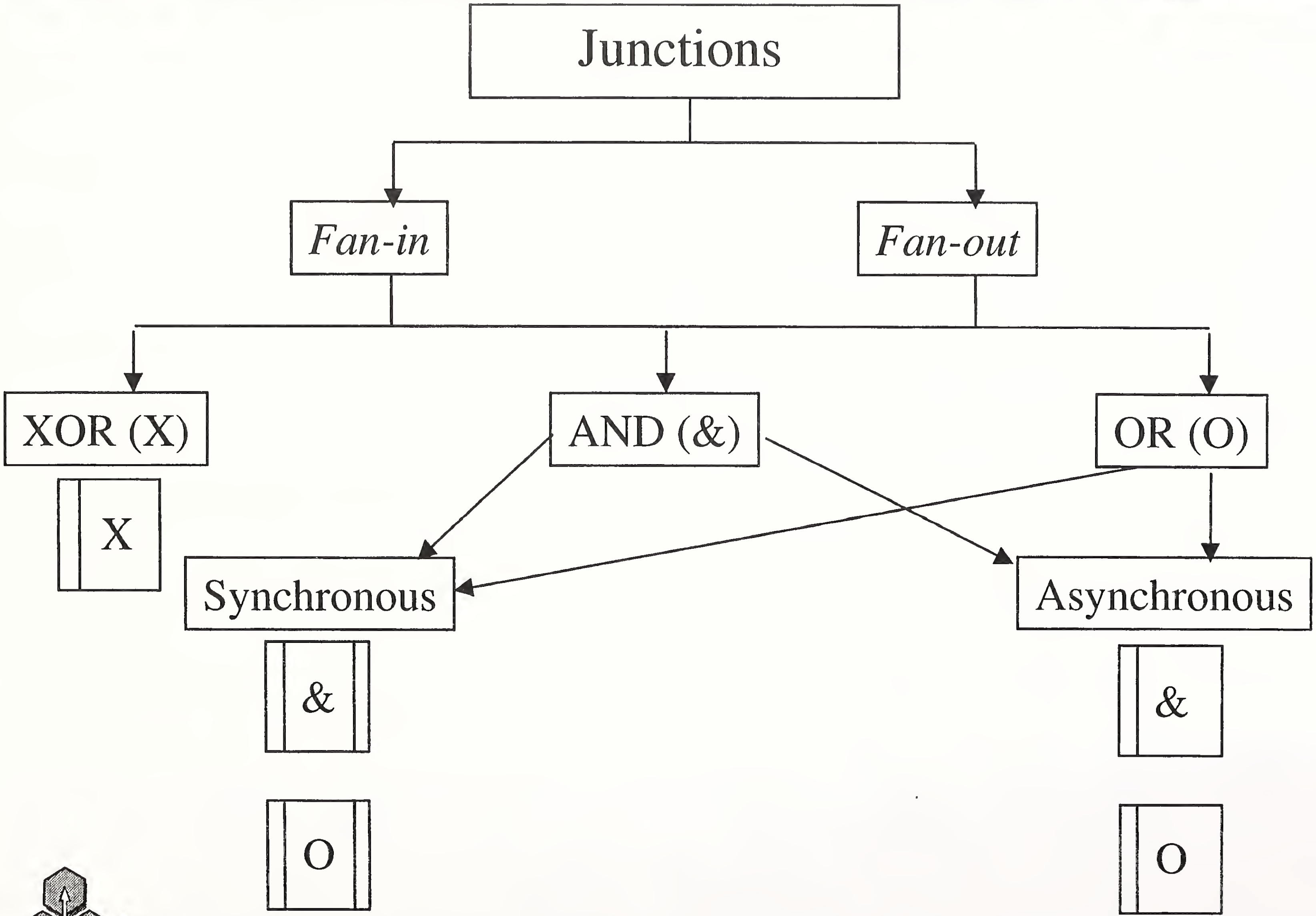
Junctions

- Junctions are used to represent logical relationships between sets of activities

The Fan-out XOR Junction indicates that only one of the activities following the junction can start after the activity preceding the junction completes



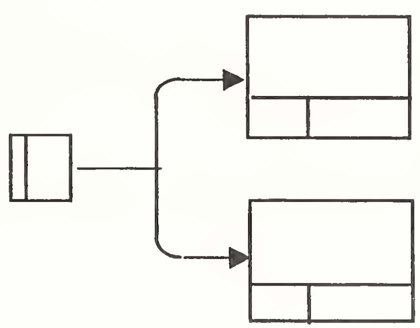
Junctions



Junctions
Fan-in
Fan-out
XOR (X)
AND (&)
OR (O)
X
Synchronous
Asynchronous
&
O
&
O

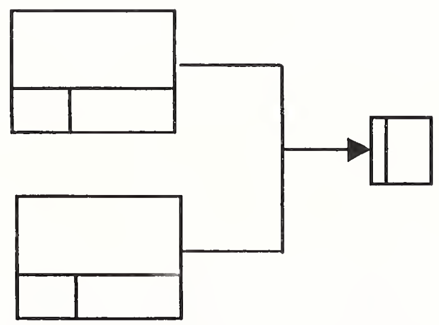
Fan-Out Junctions

Junction Type	*Interpretation*
& -- Asynchronous "AND"	All succeeding activities will start
& -- Synchronous "AND"	All succeeding activities will start, and start together
O -- Asynchronous "OR"	One or more of the following activities will start
O -- Synchronous "OR"	One or more of the following activities will start, and those that start will start together
X -- "XOR"	Exactly one of the following activities will start



Fan-Out Junctions

Junction Type	Interpretation
& -- Asynchronous "AND"	All preceding activities must complete.
& -- Synchronous "AND"	All preceding activities must complete, and complete simultaneously
O -- Asynchronous "OR"	One or more of the preceding activities must complete.
O -- Synchronous "OR"	One or more of the preceding activities will complete, and those that complete must do so simultaneously
X -- "XOR"	Exactly one of the preceding processes will complete



Process Elaborations

- Elaborations are textual descriptions of the process using the IDEF3 Elaboration Language

- Elaborations include descriptions of:

◆ <u>Objects</u> that participate in the process being described

◆ <u>Facts</u> - statements of belief about the process

◆ <u>Constraints</u> - statements about relationships that must hold for the process

IDEF3 Procedure

Process Capture Modes of Thought

- **Collect:** Acquire observations and written descriptions
  - both generalization- and instance-level descriptions
- **Classify**: Situation types, objects, object types, object states, and relations
- **Organize**: Assemble the data using IDEF3 structures
- **Validate:** Syntactic correctness; corroboration with descriptions of the actual or idealized situation
- **Refine:** Incorporate newly discovered information; Simplify the presentation; Highlight important elements of interest

Process Capture Activities

- Define the project
  - purpose, viewpoint, context
- Organize for data collection
  - organize team, develop capture plan
- Collect and analyze data
  - capture, classify, validate, refine
- Formulate process and object schematics
  - process-centered and object-centered views
- Refine and validate
  - structured review cycle

Process Capture Tool Demonstration

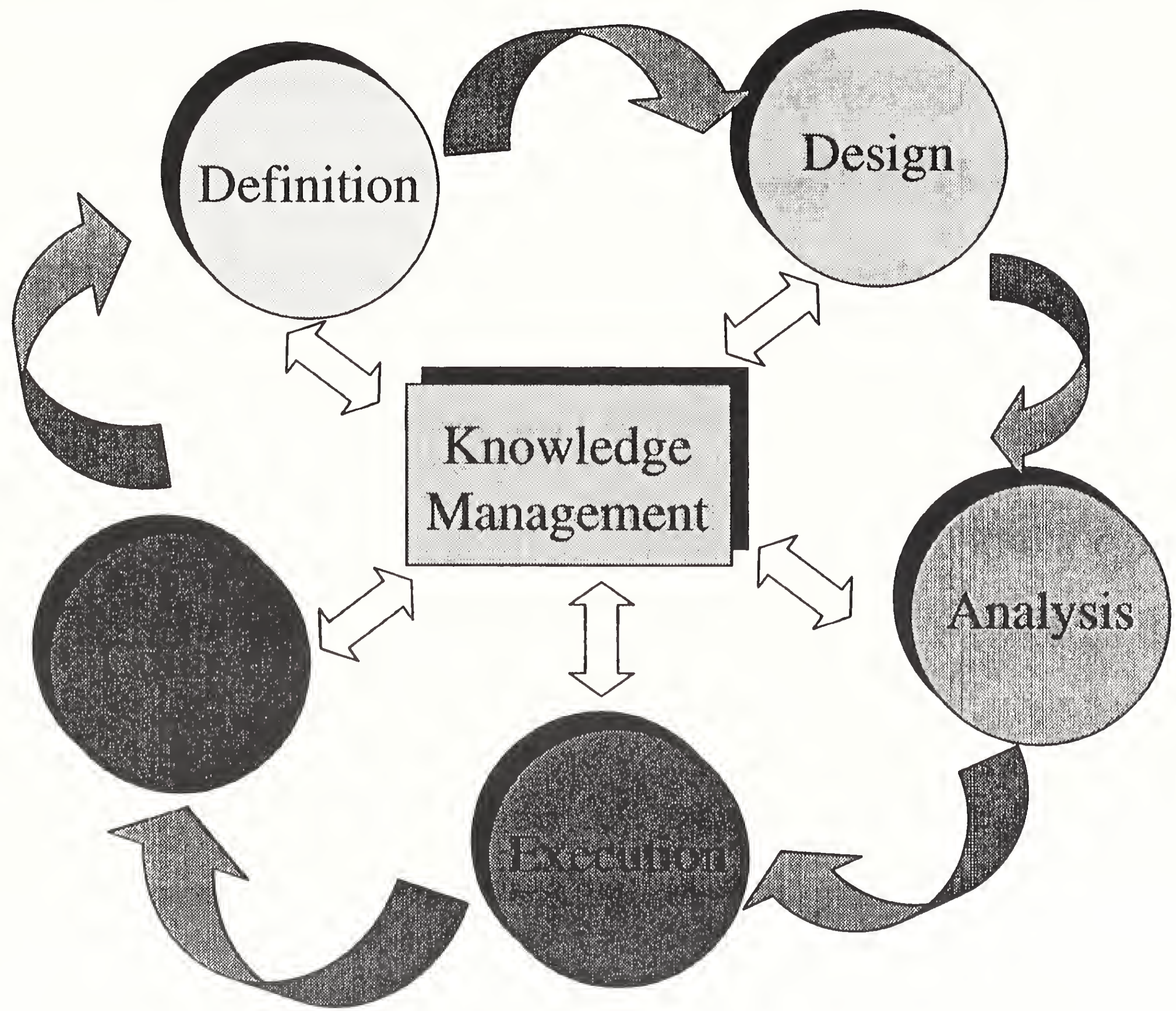
Methods and Tools for Process Design and Implementation

Richard Mayer
Knowledge Based Systems, Inc.
rmayer@kbsi.com
www.kbsi.com
Amit Sheth
University of Georgia
amit@cs.uga.edu
http://lsdis.cs.uga.edu

Outline

- Principles of process design
- Process design heuristics
- Introduction to workflow technology
- Technical challenges
- Tool demonstrations

Process Technology - A Life Cycle Perspective



Process Design

- Development of an executable specification of a process
- Design Strategies
  - Variant process design vs. generative process design
- Multiple perspectives
  - Plan design, schedule design, process planning, workflow design, agent/software behavior design
- Process design is more art than science
  - Current practice: heuristic and often ad-hoc
  - Technology has lagged industry demand
- Previous scientific efforts have focused on product design rather than process design

Principles of Process Design

Principle I

- Process-Design is a *Design* activity
  - Primarily *abductive* in nature
    - Find best practices
    - Copy and adapt them
  - Primarily iterative in execution
  - No one single solution
  - Requires cost/performance/benefit/risk tradeoffs
    - Simulation analysis
    - ABC analysis
    - Life-cycle cost benefit analysis
  - Not complete till the specification is produced

Principle II

- Process design expertise is made up of a set of skills and the knowledge of how to apply those skills opportunistically
  - Constraint management / satisfaction
  - Recognize difference between requirements and design goals
  - There is not a flow chart
  - Progress not necessarily made in a linear fashion
  - Should result in multiple alternatives that are subject to tradeoff analysis

Principle III

- "Object design" plays a central role in the process design
  - Structure, form, and content
  - Rates and volumes
  - Inputs and outputs
  - Intermediate objects
  - Interface objects
  - Object "quality" measures

Principle IV

- Processes must be specified to a level that can allow allocation to specific resources available in the execution environment
  - Decomposition into subprocesses
  - Termination condition of process design
  - Processes will change as the skills and capabilities of the people and machines change

Principle V

- Conservation Law - Physical and logical input/output contiguity must be maintained
  - Input/output of each process unit must be specified and matched with the input available and the output required at the position of the process unit in the process flow
  - Drives decomposition
  - Highly dependent on object design

Principle VI

- There will always be failures that must be addressed
  - Failure mode identification
  - Failure mode analysis
  - Failure detection sub process design
  - Failure handling sub process design
  - Robustness relative to failures

Principle VII

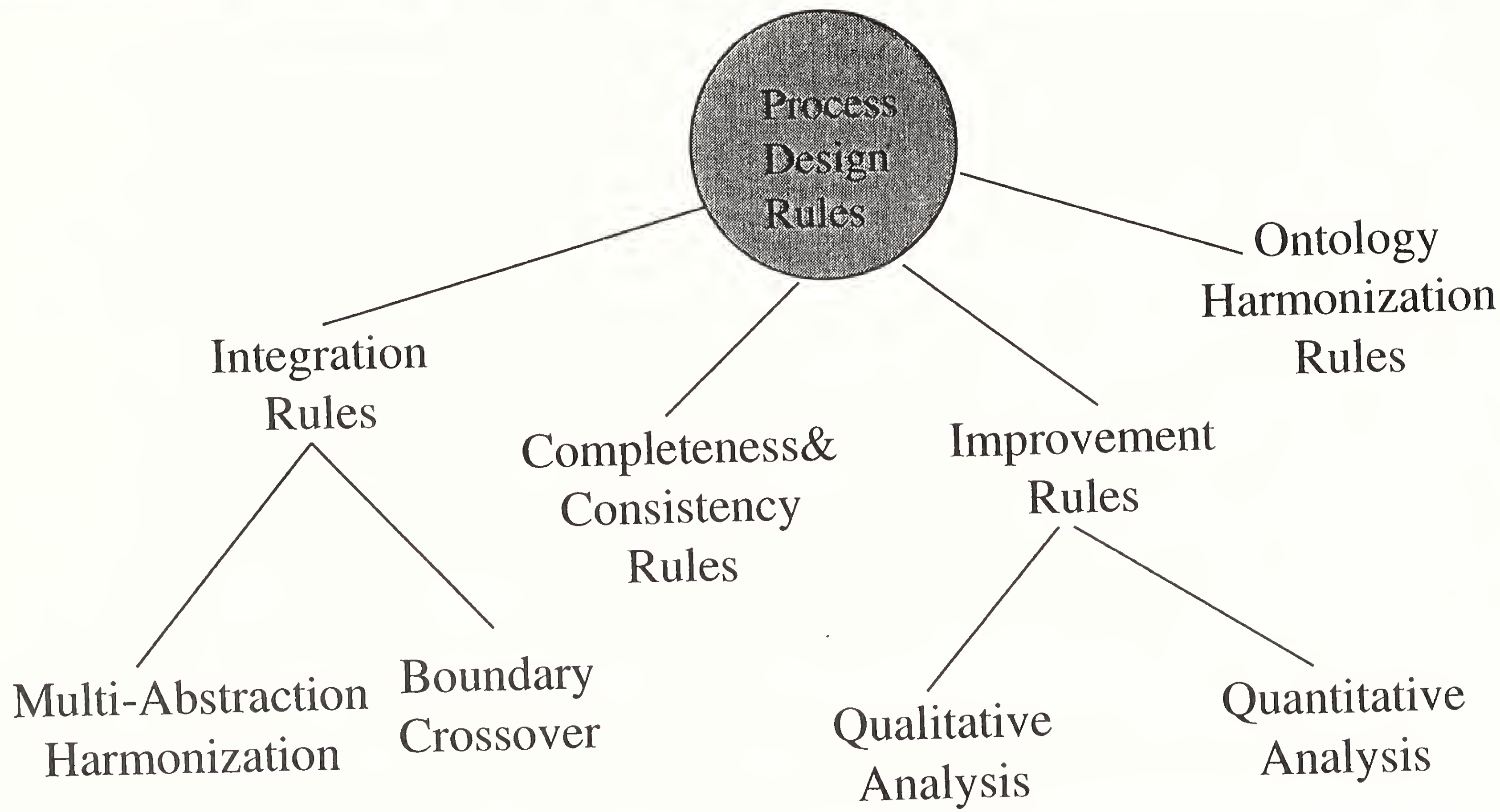
- Process design includes the design of process steps for by-product management
  - waste or scrap
  - identify
  - collect
  - dispose

Principle VIII

- Process design includes design of process steps and objects for execution coordination and management
  - Normally more than one process instantiation
  - Resource allocation
  - Work item prioritization
  - Status, performance, traceability data collection
  - Interface management

Process Design Heuristics

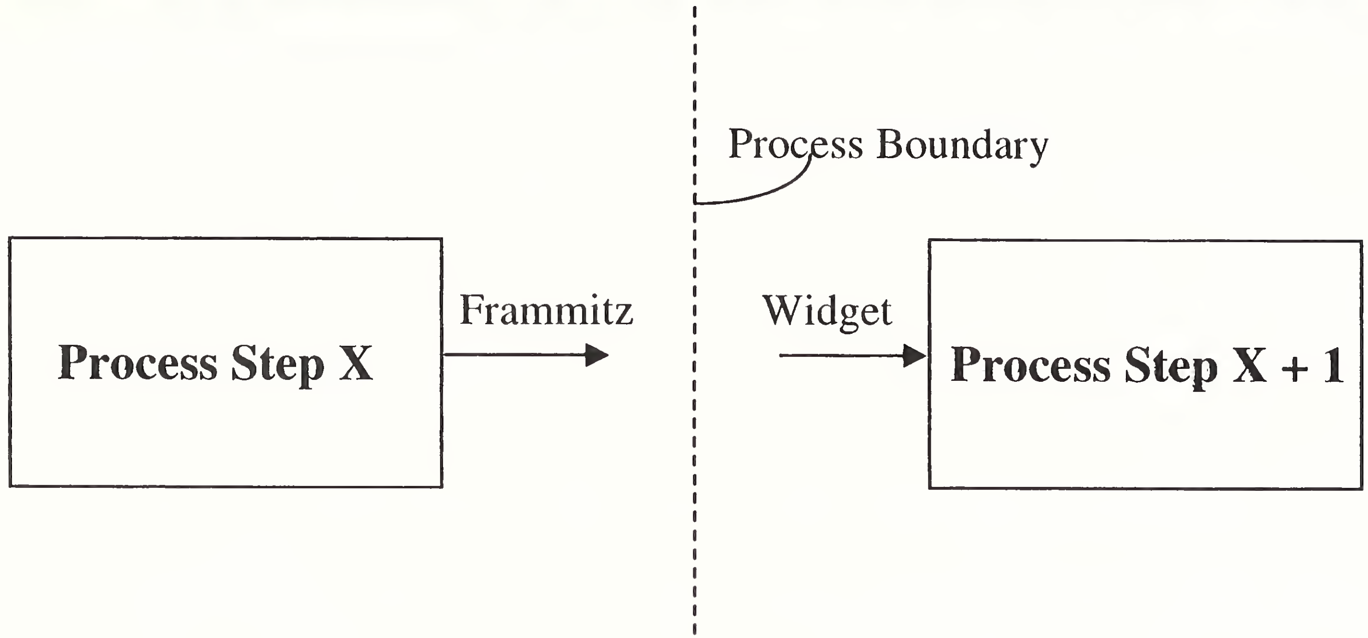
Process Design Knowledge Base



Integration Rules

- Boundary crossover mismatches
  - Rate mismatch
  - Missing inputs / outputs
  - Mismatched input / output attributes
- Inter-abstraction level disharmony
  - Time
  - Cost
  - Objects (inputs, outputs, resources)

Input - Output Mismatches



Completeness & Consistency Rules

- Completeness
  - Is the model complete relative to design goals
    - Check for missing information that inhibits
      - trade-off analysis
      - implementation
- Consistency
  - Check for logical inconsistencies
    - Example: Process P produces A, B, C as output, but requires A and B as inputs

Process Improvement Rules

- Qualitative Analysis
  - Approximate estimates of performance metrics
    - time
    - cost
    - concurrency
    - complexity
    - variability
- Quantitative Analysis
  - Robust estimates of performance based on
    - systems simulation
    - activity based costing
    - schedule analysis techniques (CPM, PERT)

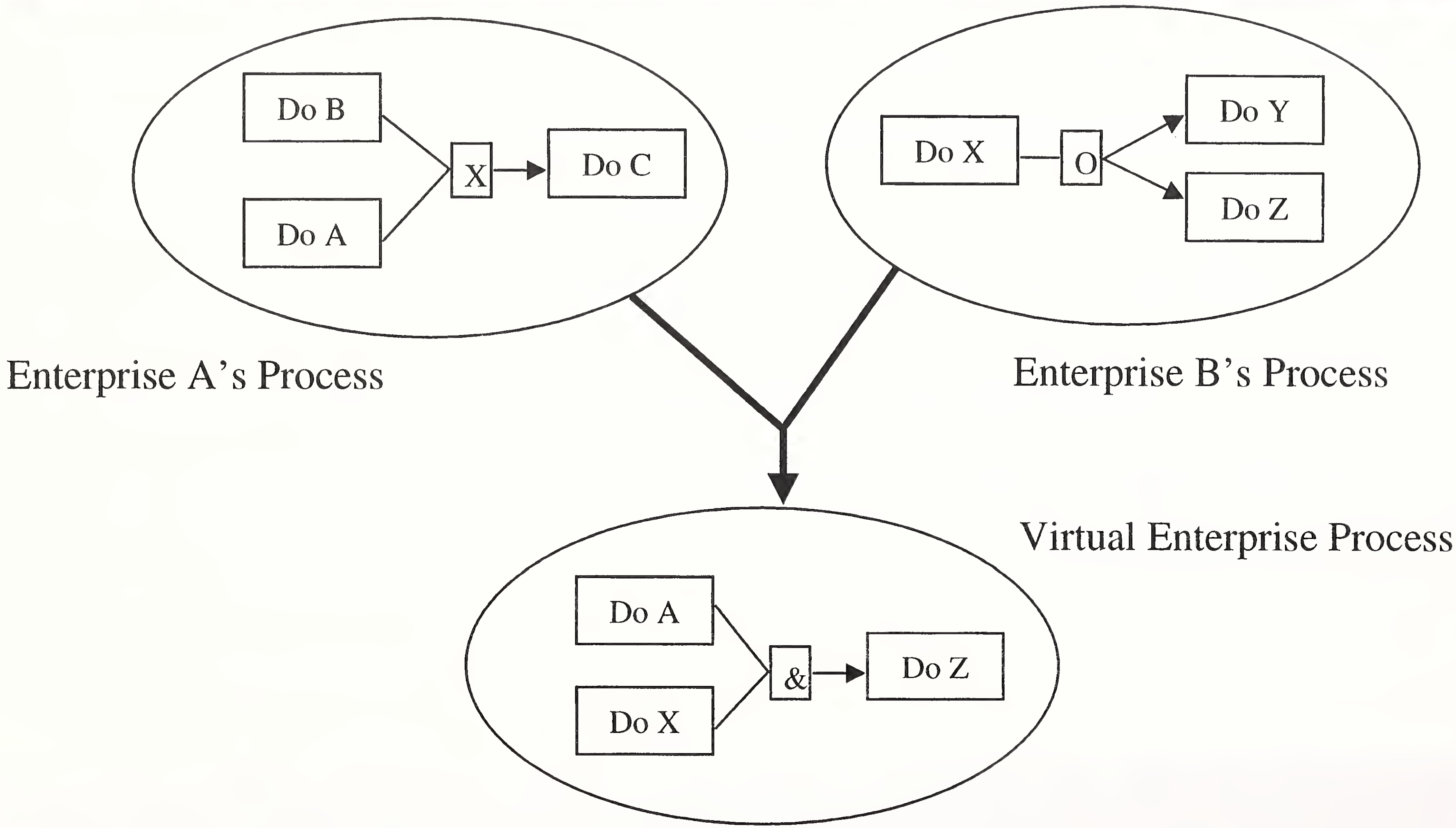
Ontology Harmonization Rules

- Identification of potential mismatches in processes based on assessment of domain ontologies
  - Name conflict resolution
    - Postulating object identity based on observed evidence of relationships
  - Concept disambiguation
    - Discovering differences in meaning of synonymous concepts based on analysis of concept characteristics (attributes and relations)
  - Knowledge discovery
    - Identification of new associations (useful for robust process implementation) based on axiomatic analysis of current ontology

Process Design Steps

- Specify goals and metrics
- Plan design project
- Identify templates and re-usable processes
- Bring models into common environment
- “Stitch” models together
- Analyze draft integrated process
  - Qualitative, quantitative, and immersive analysis methods
- Resolve issues and optimize
- Implement

Process Composition



Process fragments are "stitched together" to produce an integrated process

Stitching Processes Together

- All models in common environment
  - EPIF-enabled knowledge sharing
- "Cut and Paste" together (IDEF3)
- Identify mismatches through visual inspection
  - Functional view assessment (IDEF0)
  - Ontology assessment (IDEF5)

Technical Challenges and Gaps

- Process design is an art
  - not taught in our curricula
  - requires systematization of practical knowledge
- Need for process design research and development
  - Theory and principles
  - Methods
  - Tools
- Need to harmonize process design know how from multiple communities and multiple application domains
  - Adapt knowledge from relatively mature areas such as product design and system design

Process Design Tool Demo

Process Implementation:
Where the Rubber meets the Road

Overview of Workflow Management: Beyond Process Modeling

NIST PIT Workshop, Gaithersburg, March 13, 1998.

Amit Sheth
rge Scale Distributed Information System Laboratory
University of Georgia
(706) 542-2310, amit@cs.uga.edu
http://LSDIS.cs.uga.edu/

Organizational Process

An organizational process is a collection of activities related to a specific commitment, adding value to a product of an organization.

Example: processing damage claims in an insurance company.

Workflow Process

A workflow process is an automated organizational process.

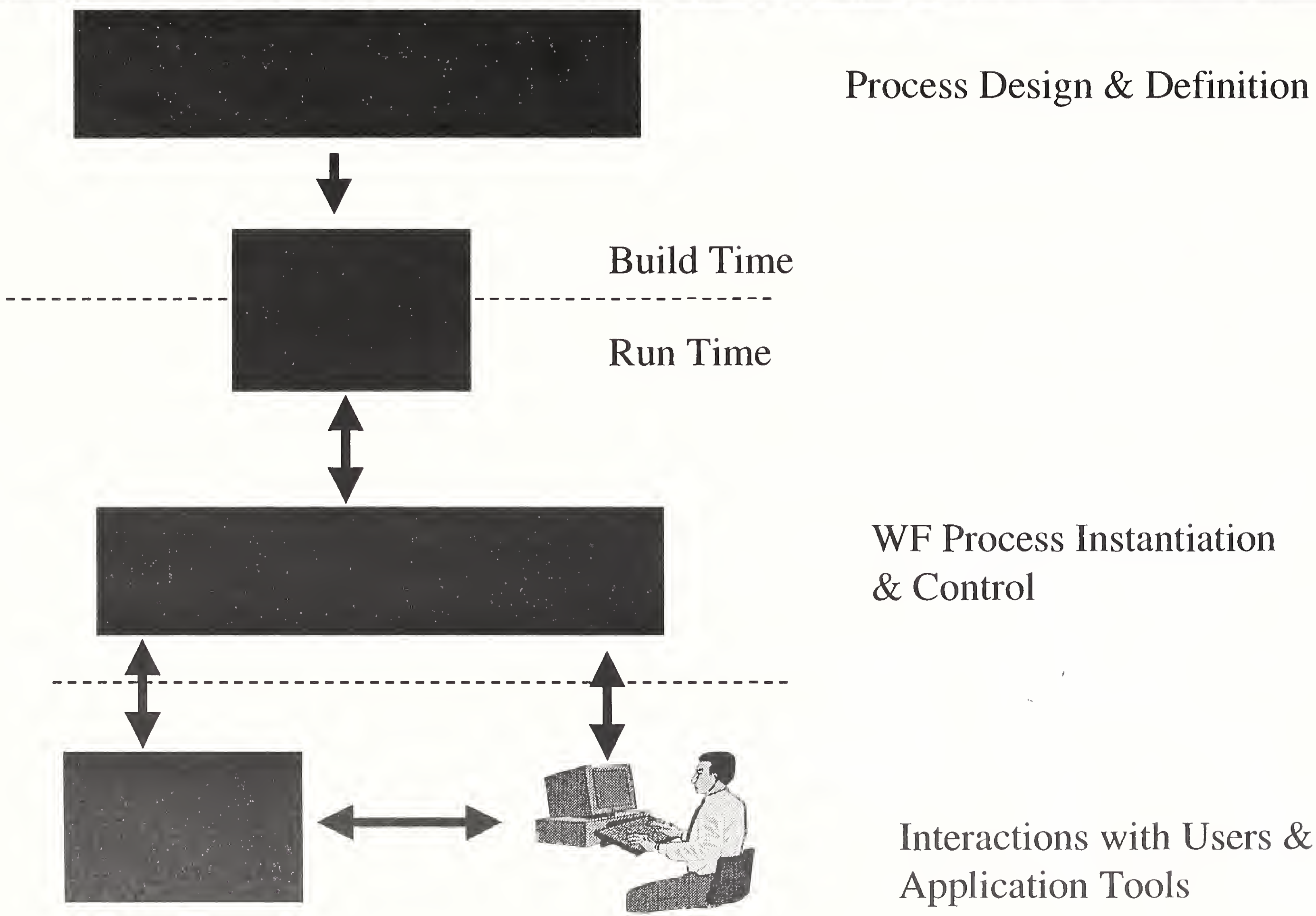
Example: processing damage claims in an insurance company "orchestrated" by a workflow management system.

Workflow Management

Workflow Management (WFM) is the automated *coordination*, *control*, and *communication* of work, *both of people and computers*, in the context of *organizational processes*, through the execution of software ....

[Jbosten]

Workflow Management Issues (WfMC)



Workflow Management System

- A system that defines, creates and manages the execution of workflows through the use of software, running on one or more workflow engines, which is able to interpret the process definition, interact with workflow participants and, where required, invoke the use of IT tools and applications. [WfMC]
- A set of tools providing support for process definition, workflow enactment, and administration and monitoring of workflow process.

The lure of workflow: *it fits the trend*

Workflow fits nicely with other trends, such as

» productivity gains,
» re-engineering,
» downsizing / right-sizing,
» network computing,
» groupware, and
» client-server computi

Benefits of Workflow Technology

- Organize, schedule, control and monitor process
- Help understand/improve process (analysis, simulate, reengineering)
- Reduce paper work
- Support on-line data entry where data originates; support data exchange and transactions across independent enterprises (EDI)

In most general form, workflow technology can be used to support programming-in-the-

The lure of workflow: a large market

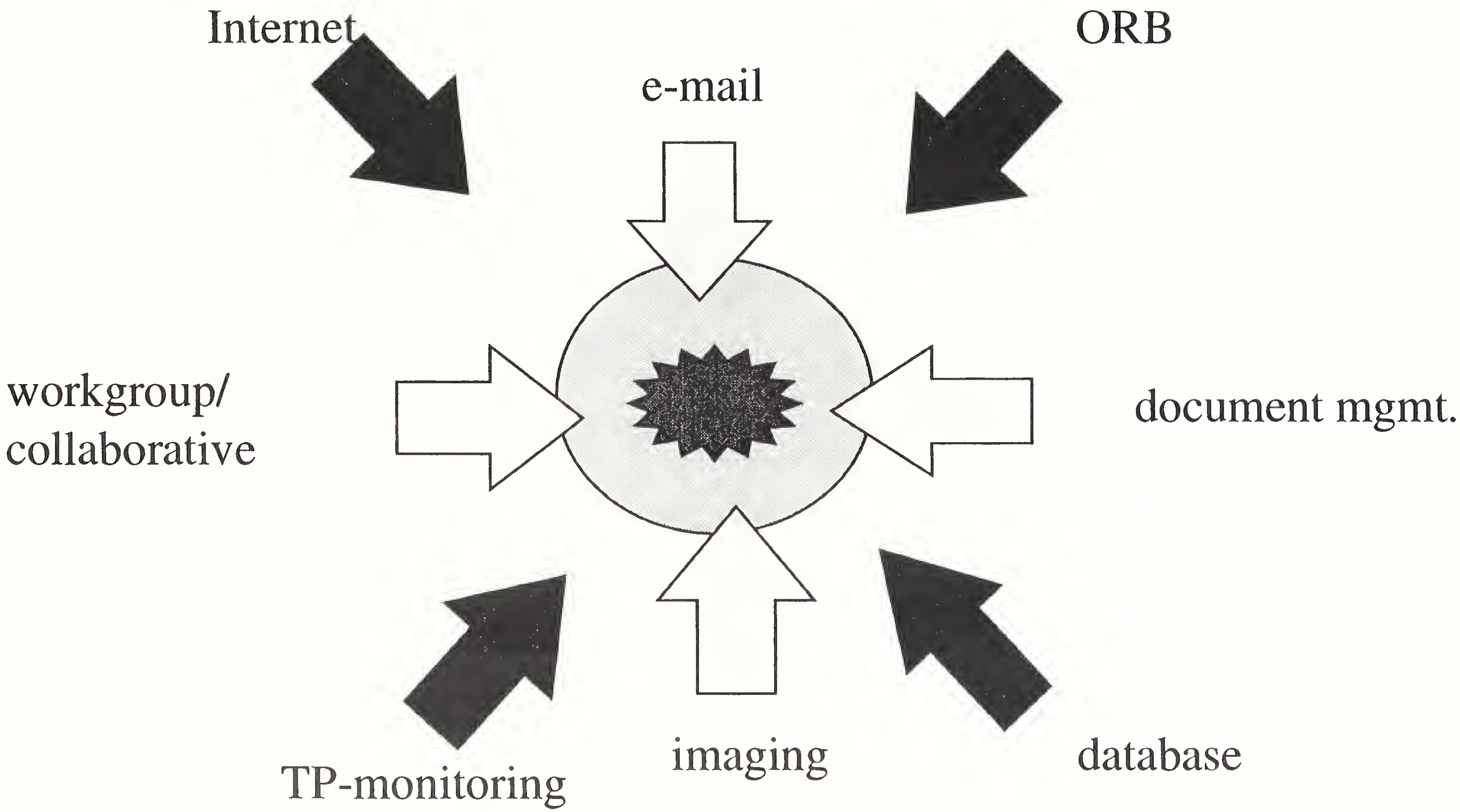
Market/Revenue Forecast for Workflow Software ($-mil)

Year	Workflow all (Services, WF-enabled Apps.)	Generic Workflow Tools	Transactional Workflow
1992	226(DL), 186(DL)	115(DL)	
1993	628(ID)	250	44
1994	1200(ID)	540	106
1995	1800(ID), 2000(CW)	810	184
1996	2500(IDC, DL)	1120(DL)	293
2000	[illegible]	2000(Ovum)	

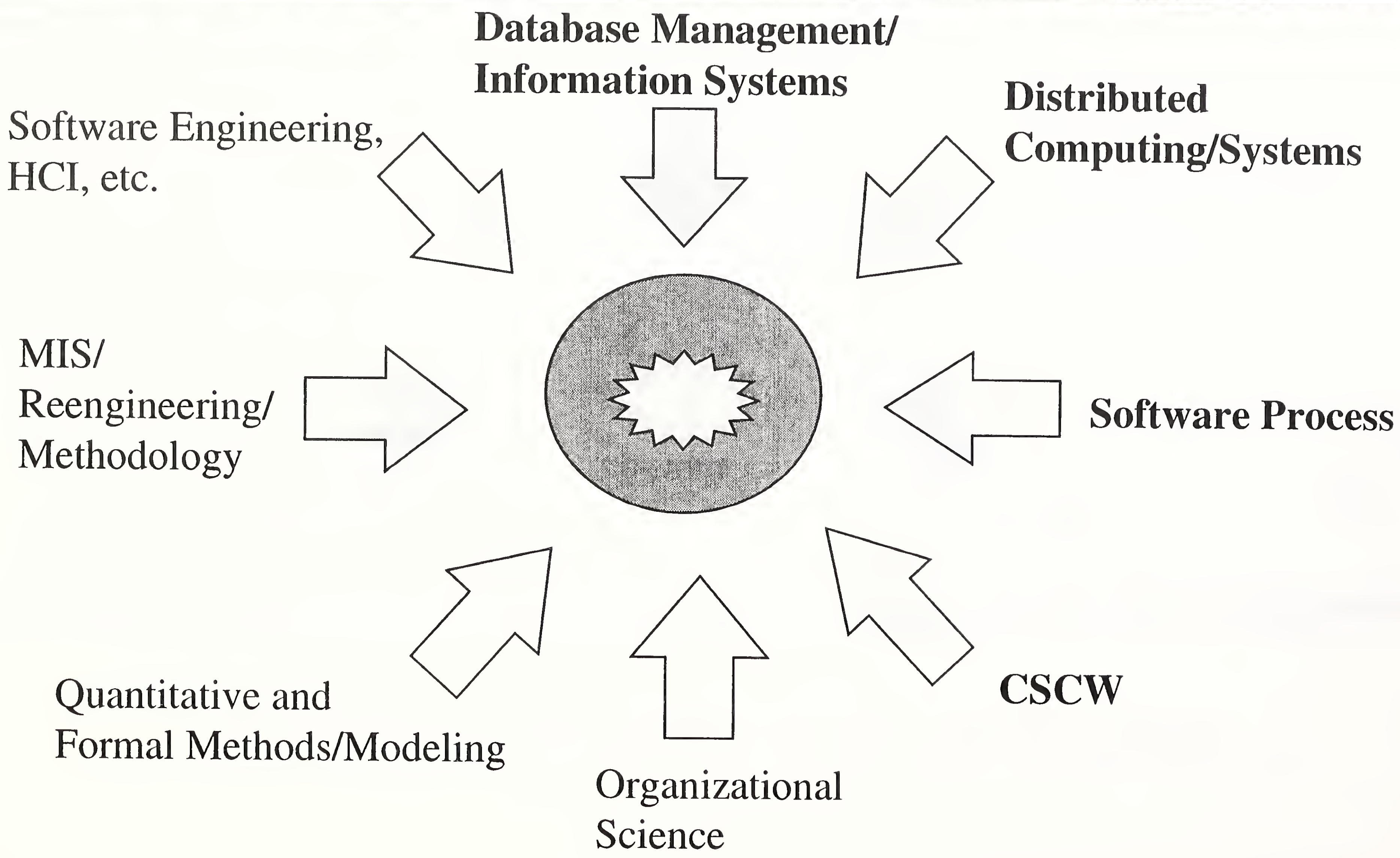
Sources: ID = IDC & Advante; DL = Delphi Consulting; IT = International Data Corp., ***Communications Week, July 22, 1996***.

Workflow
and Related Technologies

Market Approaches to Workflow



Research Disciplines Contributing to to Workflow Management



Workflow Application Segments

PRODUCTION:

High performance document processing and transaction applications
(claims processing, credit approval, etc....)
(highly structured, repetitive process, high throughput)

ADMINISTRATIVE:

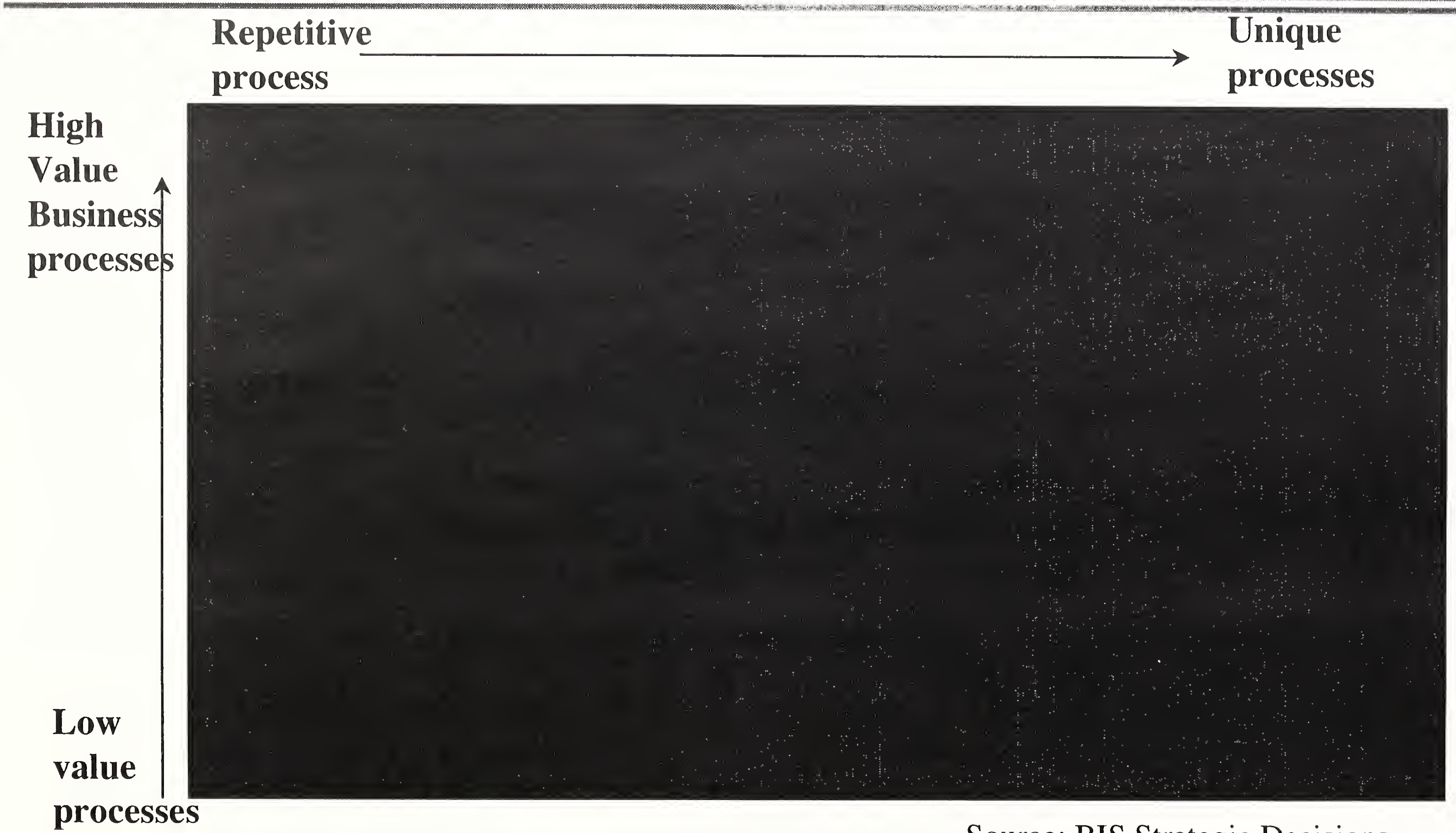
Automating administrative functions
(customer records, communication services, etc....)
(semi-structured, lower throughput)

AD HOC / COLLABORATIVE:

Collaborative and ad hoc work processes
(packaged desktop applications, e-mail, scheduling, research, projects)
(unstructured, low throughput, fewer participants)

Source: Doculabs report on workflow products

Workflow Application Segments



Source: BIS Strategic Decisions

Workflow Products (Partial List)

- Action Workflow System Action Technologies Inc. http://www.actiontech.com/
- CSE/Workflow (CSE Systems Corporation) http://www.csesystems.com/
- Delrina FormFlow(Delrina)
- DM/Workflow(Intergraph)
- EPIC/WF(Computron)
- FlowLogic (FlowLogic Corporation) http://www.flowlogic.com/
- FlowMaker (Workflow)
- FlowMan(Logical Software Solutions)
- FlowMark (IBM) http://www.software.ibm.com/ad/flowmark/
- InConcert (InConcert Inc.) http://www.inconcertsw.com/
- FloWare (BancTec Inc.) http://www.plx.com/floware/
- GroupFlow(Pavone)
- InConcert(InConcert)
- JetForm(Jetform)

Workflow Products (Partial List)

- Keyflow(Keyfile)
- KI Shell(UES)
- Livelink Workflow(Odesta)
- LinkWorks(DEC) http://www.digital.com/info/linkworks/
- Lotus Notes(IBM/Lotus)
- METEOR (Infocosm, Inc.) http://www.infocosm.com
- Office.IQ workflow and document management software (Portfolio Technologies Inc.) http://www.officeiq.com/
- OmniDesk RouteBuilder (SIGMA/Wang)
- OPEN/workflow (Eastman Software, Wang) http://www.eastmansoftware.com
- Optix Workflow (Blueridge)
- Plexus FloWare (Recognition/BancTec)

Workflow Products (partial list)

- ViewStar System(ViewStar)
- ProcessIT(NCR)- Plexus FloWare OEM
- Staffware (Staffware) http://www.staffware.com/
- TeamWARE Flow (ICL/ TeamWare)
- Ultimus (Ultimus) http://www.ultimus1.com/
- Visual WorkFlow (FileNet) http://www.filenet.com/
- WorkMAN (Reach Software)
- WorkVision(IA) WorkFlow (CSE Systems, Computer & Software Engineering) http://www.csesys.co.at/
- WorkParty (Siemens Nixdorf) http://www.sni.de/public/sni.htm
- WebFlow (Workflow Management on the WWW, Cap Gemini Innovation) http://webflow.cginn.cgs.fr:4747/

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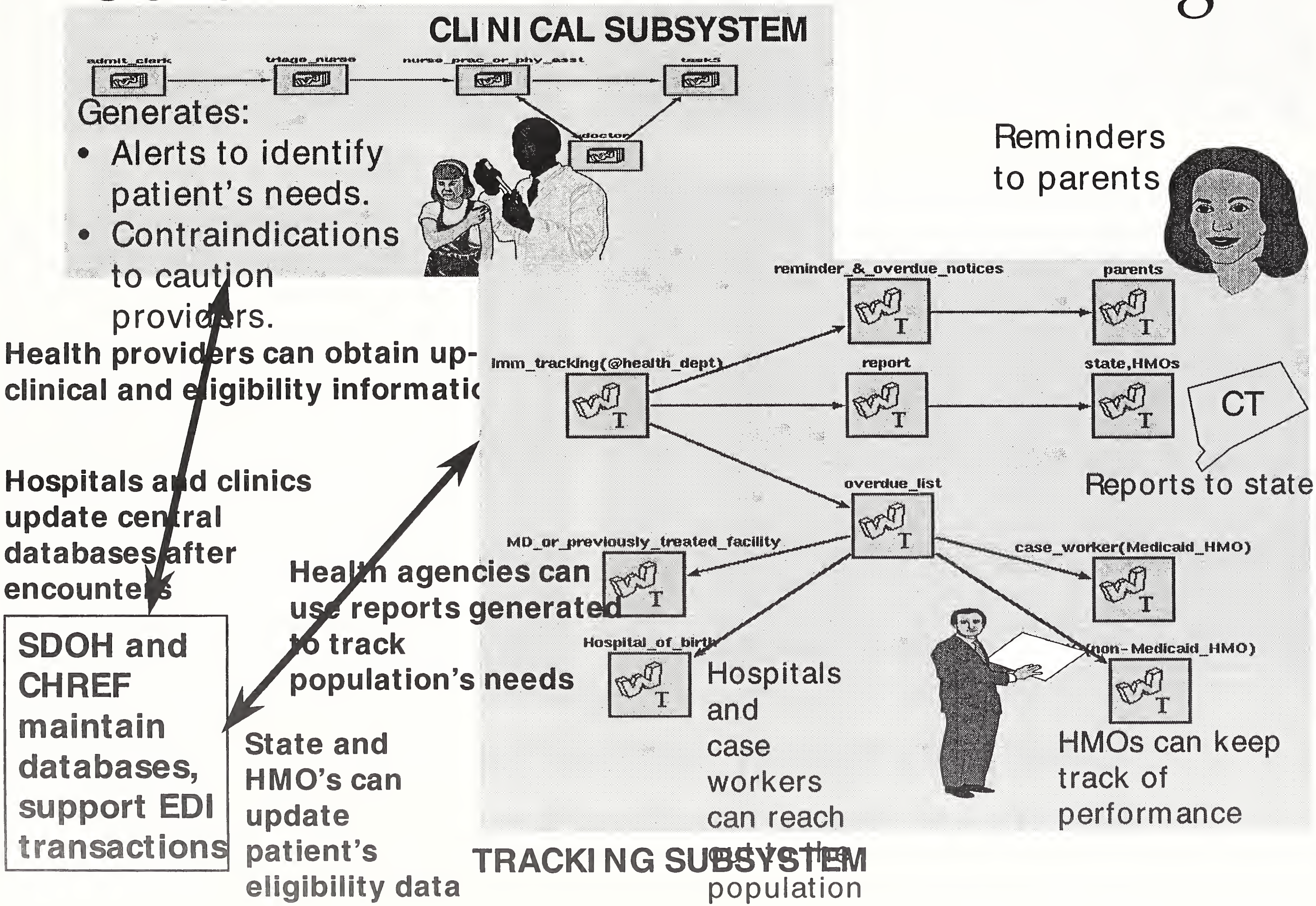
A Comparison of (mostly) Research Workflow Management Systems (from CodAlf DSEJ paper)

				METEOR2	FlowMark			
				both	no			
				both	no			
				yes	yes			
				yes	yes			
				no	no			
				going on	yes			
				yes	yes			
				yes	no			
				yes	no			

A Quick Look at a Realistic Example

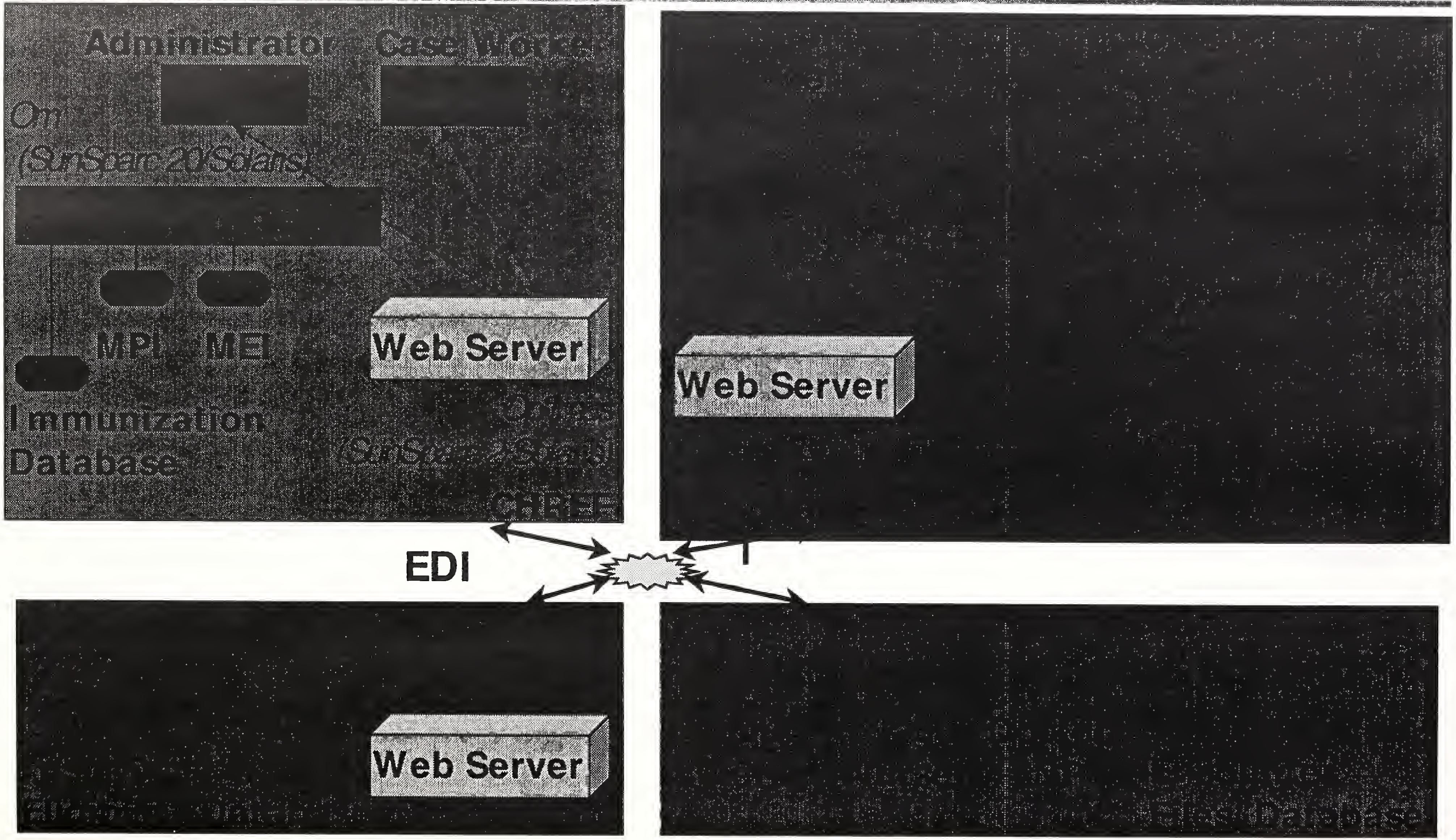
Requirements/ Specifications by
CHREF

Schematic of Immunization Tracking



Implementation Testbed: Immunization Tracking Demo

try out this testbed at http: //lsdis.cs.uga.edu/workflow



Characteristics of Large-Scale Real-World Workflow Applications

- HAD computing environments
- Humans, legacy applications, and other non-transactional tasks
- Multiple communication infrastructures
- Organizational requirements (roles, authentication, security, etc.)
- Heterogeneous multimedia data
- Dynamic and virtual enterprises
- Electronic commerce

Observation

- Current workflow products typically
  - » have client/ server architecture
  - » are web- enabled (but not web- based)
- The products can provide support for 80%of all possible workflow (work coordination) applications that
  - » are relatively simple, repetitive
  - » predominantly require human involvement (user/ manual tasks), such as office automation

What is lacking?

- Support for other 20% of the enterprise-wide workflow applications that are typically mission-critical (hence higher value) and require better support for
  - » existing/legacy applications
  - » HAD environment
  - » error handling, automatic recovery
  - » scalability
  - » adaptive, configurable, dynamic workflows, WfMSs
  - » integral support for coordination and collaboration
  - » mobility

Workflow Management System:
Conceptual Architecture (*system components*)

PM Toolkit

- process specification
  - process view
  - org. view
- process analysis re- engineering
- TQM advisor
- ...

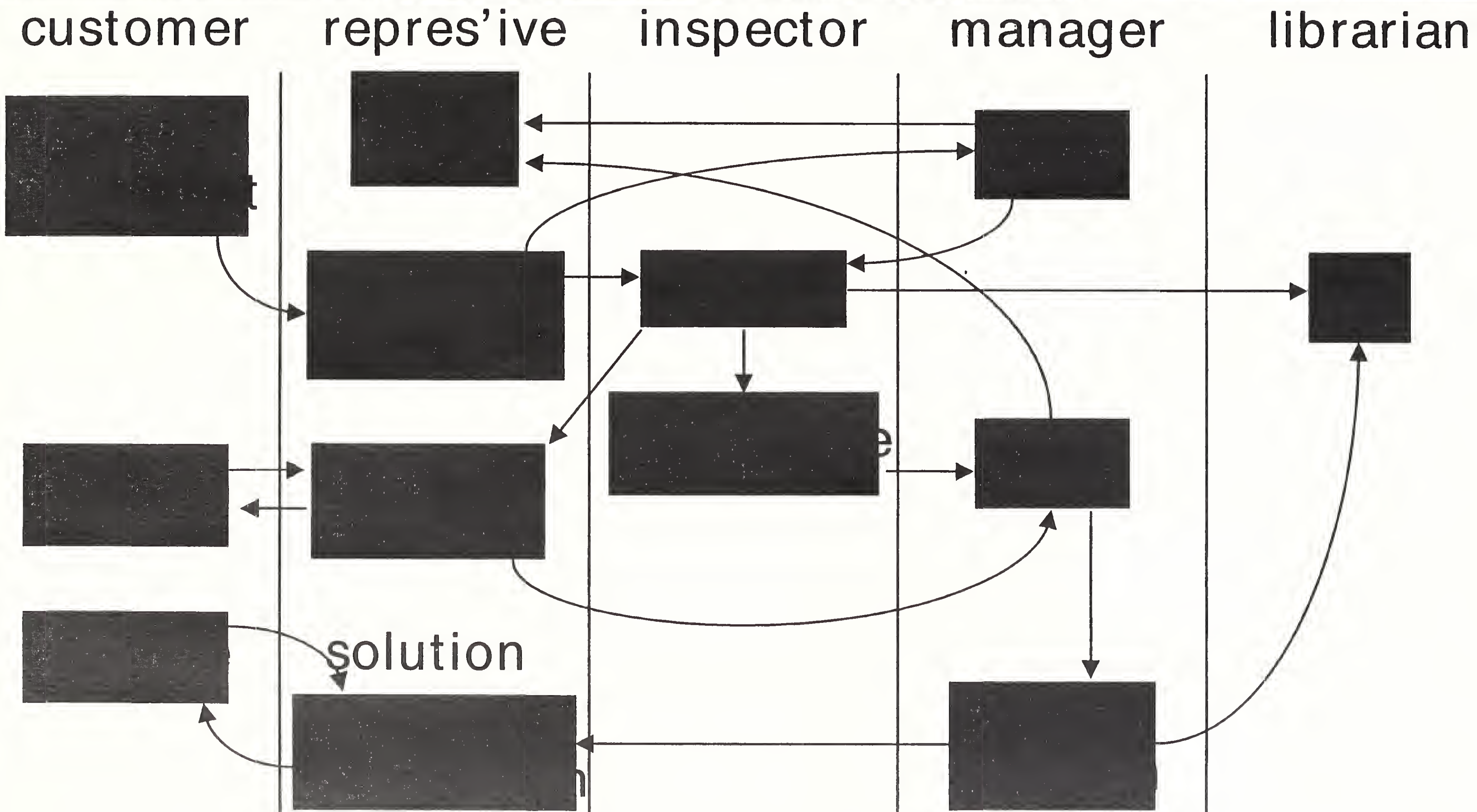
WF Development Toolkit

- graphical workflow design
- testing
- simulation
- animation

WF Enactment Service (run-time system and tools)

- scheduling
- task manager/ interfaces
- processing entities
- monitoring
- tracking
- reporting
- ...

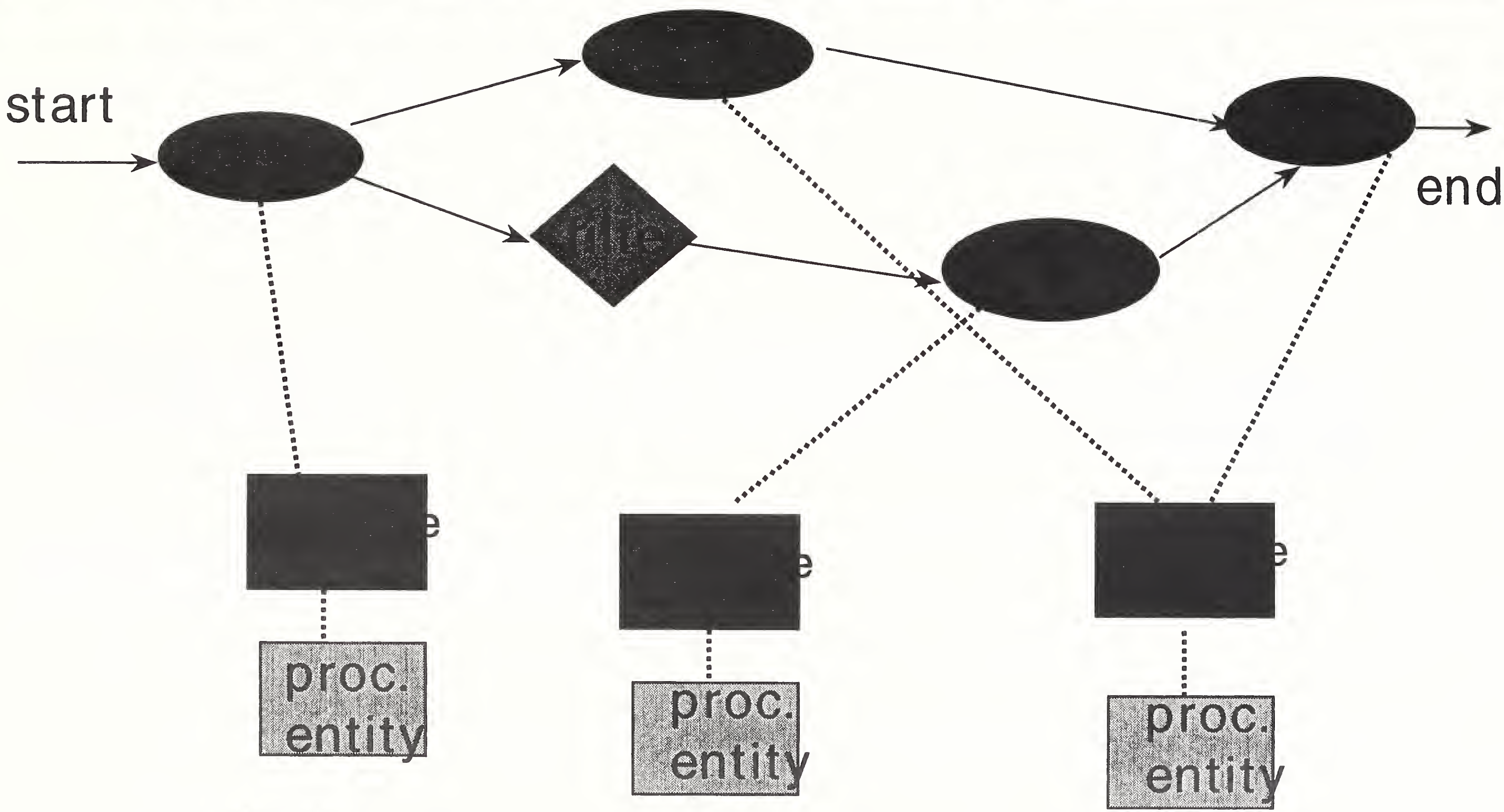
Process Model



Thanks: Stef Joosten

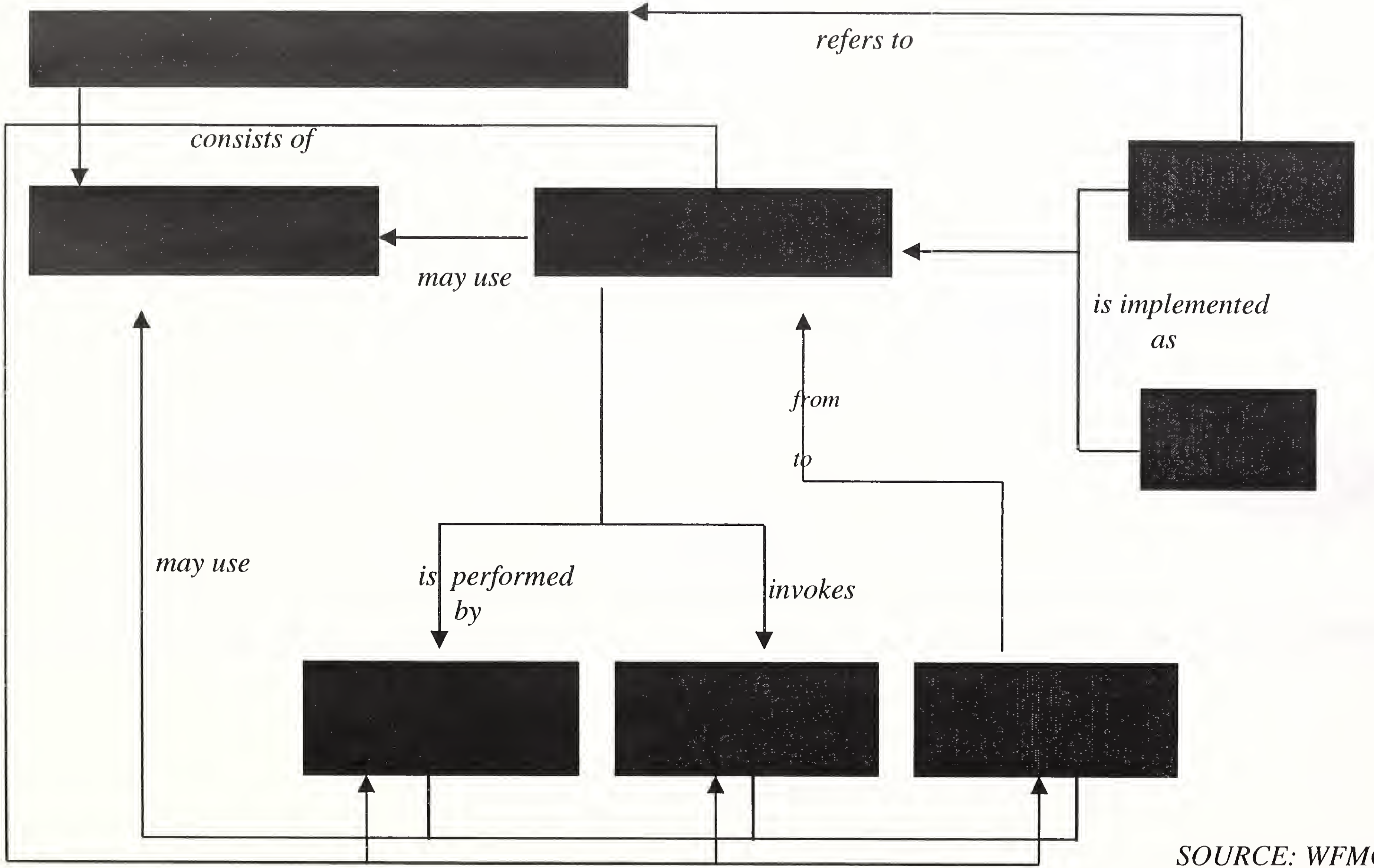
Workflow Models

A Workflow Process Model
(high level view)



from the ***METEOR*** *(Managing End-To-End OpeRations) system*

Workflow Process Definition Meta Model



SOURCE: WFMC

Basic Model Components

- Workflow (process) class (schema) to model a(n) (business/ organizational) process
- Task, activity or step
- Task coordination/ linking or Control flow (serial/ parallel- resync/ list/ queues/ network, rules/ triggers, dependencies/ conditions)
- Data flow or sharing (explicit passing, shared data, common variables)
- Processing entities: Users - - roles and authorization, worklists; Information Systems

Types of Tasks/Activities

- user tasks involving humans in processing task
- application tasks involving
  - » scripts for terminal emulation to remote systems
  - » application programs/ systems providing data manipulation (filters)
  - » predefined interfaces to legacy application systems (e.g., Bellcore "contracts")
  - » stored procedure calls
  - » client programs or servers invoking other servers
  - » database transactions

Types of Processing Entities

- humans (may appear as a GUI; may use document/image processing systems and applications)
- script interpreters and compilers(for processing scripts and application programs)
- (legacy) application systems
- servers in client-server and transaction processing systems
- DBMSs

Additional Modeling Features

- Tasks: non-transactional, transactional
- Execution environment/infrastructure/configuration : execution location, interfaces
- Deadline
- Exception Handling (Error Handling, Recovery) specification

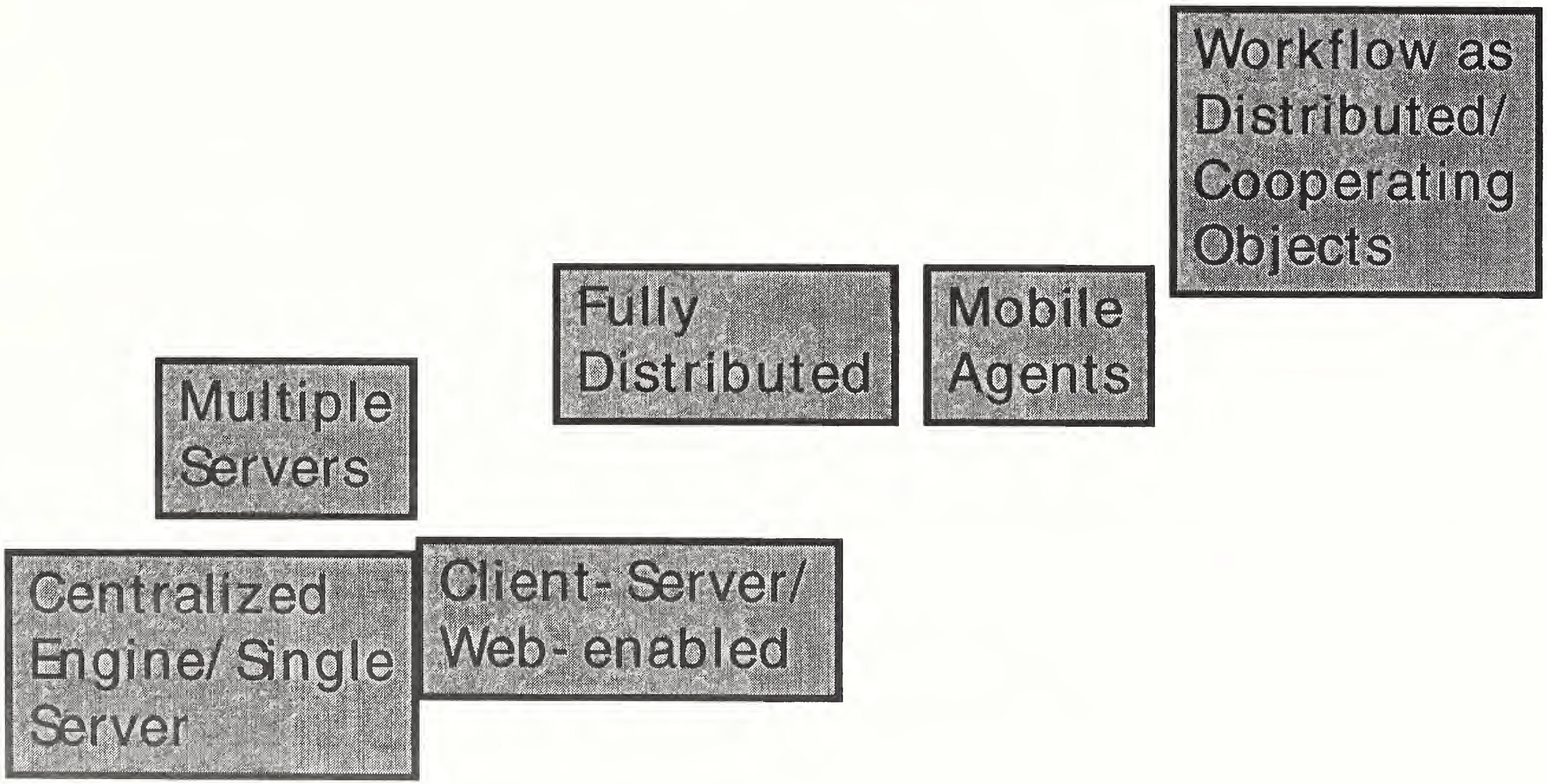
WfMS Architectures

WFMS Architectures - I

- Message oriented (the "lightweight" approach)
  - » workflow process definition is part of messages
- Repository oriented (the "heavyweight" approach)
  - » workflow process definition is stored in a repository/ database

Trade- off: infrastructure technology needed, robustness, ease of modification

WFMS Architecture - II



Maturing Infrastructure: A Driving Force

e-mail	Early 90s- already mature
Workgroup(Notes), OLE, ActiveX	1993 - now mature
Distributed Object Management (CORBA)	1995 (R) - 1998 (P)
TP Monitors	
Web, Java, Javascript,	1996 (R)
	1995 (R) - 1997/ 1998 (P)
Agents	1996 (R)

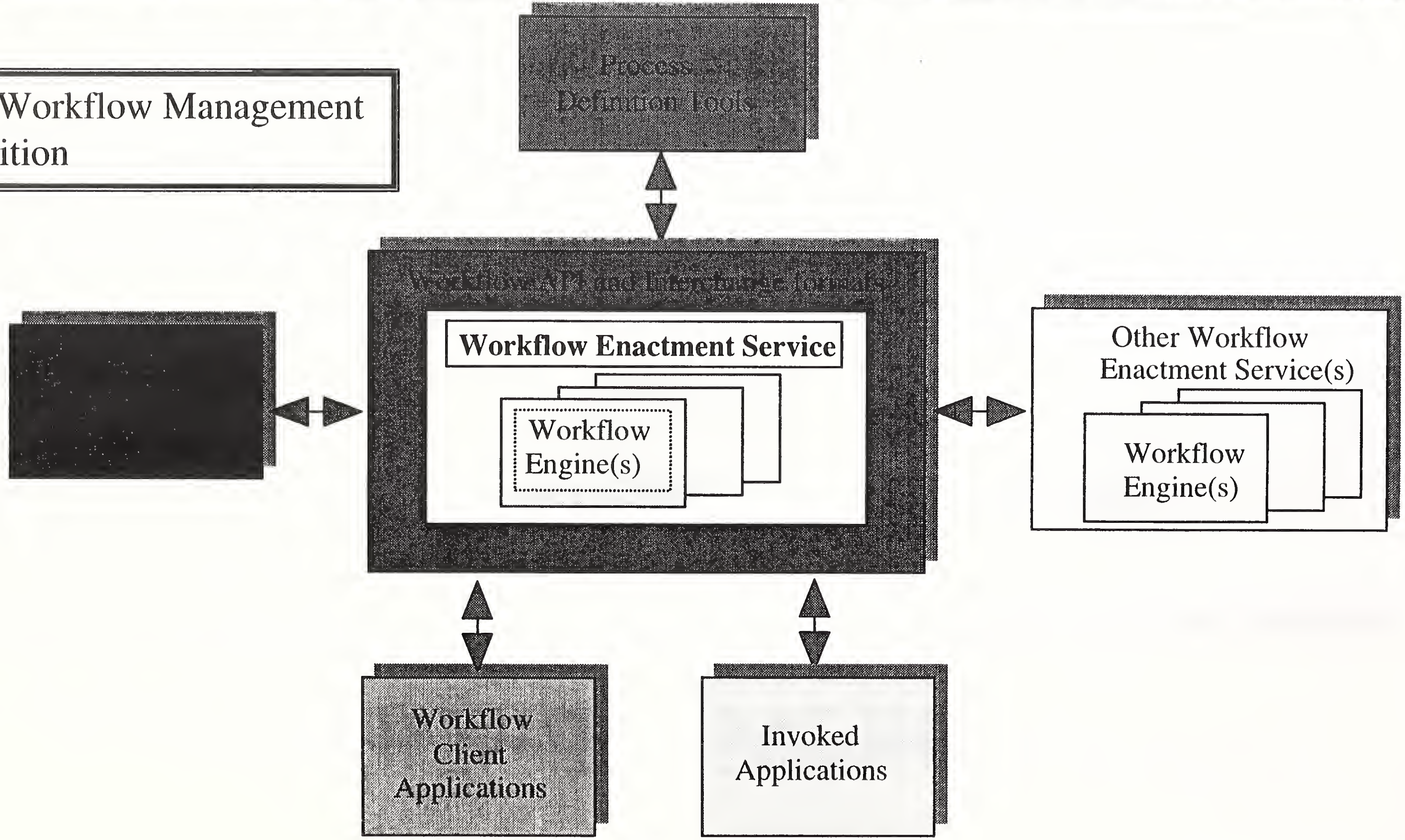
R: first research prototype, P: first product

Standard I: WFMC

- Non-profit organisation founded 1993
- Mission is to promote the use of workflow through establishment of standards for
  - » software terminology
  - » interoperability
  - » connectivity
- Over 100 members

WfMC Reference Model and APIs

The Workflow Management Coalition



Standard II - OMG Workflow Facility

http://wwwdb.inf.tu-dresden.de/wf-wg/

Standard II - OMG Workflow Facility

(Snapshot of on-going work)

	NOTEL	jFlow	EDS
Workflow metamodel-contents	no organizational aspt	workflow instance	workflow instance
-formality	high	low	low
-extendibility	Yes	Yes	Yes
Workflow enactment	Yes	not specified	not specified
Workflow monitoring	Yes, passive	Yes, events	Yes, passive
Workflow audit trail	Yes	Yes	Yes
nesting of workflows	Yes	Yes	Yes
Workflow schema definition	Yes	No	No
usage of CORBAservice	indicated	indicated	No
usage of CORBAfacility	No	No	Yes (BOF)
glossary	Minimal	WfMC	Yes, adequate

[Schultze, Bussler, Meyer-Wegener]

Relevant Research Efforts

- *ORBWork:* Fully distributed ORB-based Workflow Enactment System for $METEOR_2$
  `http://lsdis.cs.uga.edu/workflow`
- *WorCOS:* Fully distributed, modular workflow management system using CORBAservices
  `http://wwwdb.inf.tu-dresden.de/WORCOS`
- *Reliable Workflow System:* Workflow management on top of an ORB and the Arjuna transaction system
  `http://arjuna.ncl.ac.uk/WorkflowSystem/index.html.`
- CodALF, others ....

[Schultze, Bussler, Meyer-Wegener]

WFMS Features - I

- Monitoring, tracking, auditing, reporting
- Authorization; Security
- Interoperability, WfMC interfaces
- Multiple computing platforms and communications infrastructures
- Load balancing
- Versioning and life-cycle
- Scalability: Partly distributed enactment service (multiple server support); Fully distributed enactment service (engine)

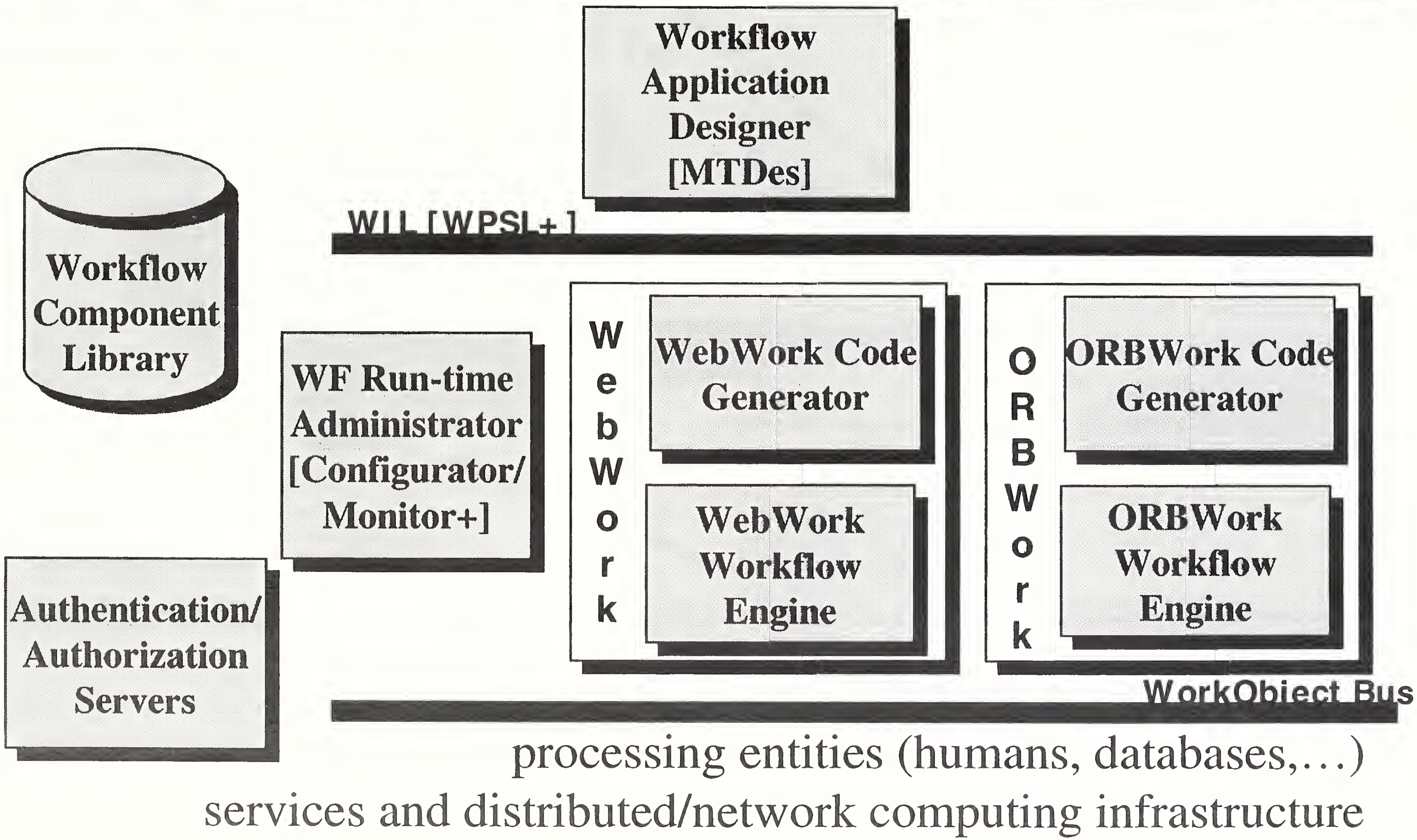
WFMS Features - II

- Refinement and reuse, testing
- Visualization and Animation; Simulation; What-if analysis and Reengineering
- Transactional support
- Integrity/ Synchronization/ CC (data access, within workflow, across workflows)
- Error handling; Automatic and manual recovery/ restart, robustness
- Adaptive/ Dynamic workflow support-- change definition for workflow in progress

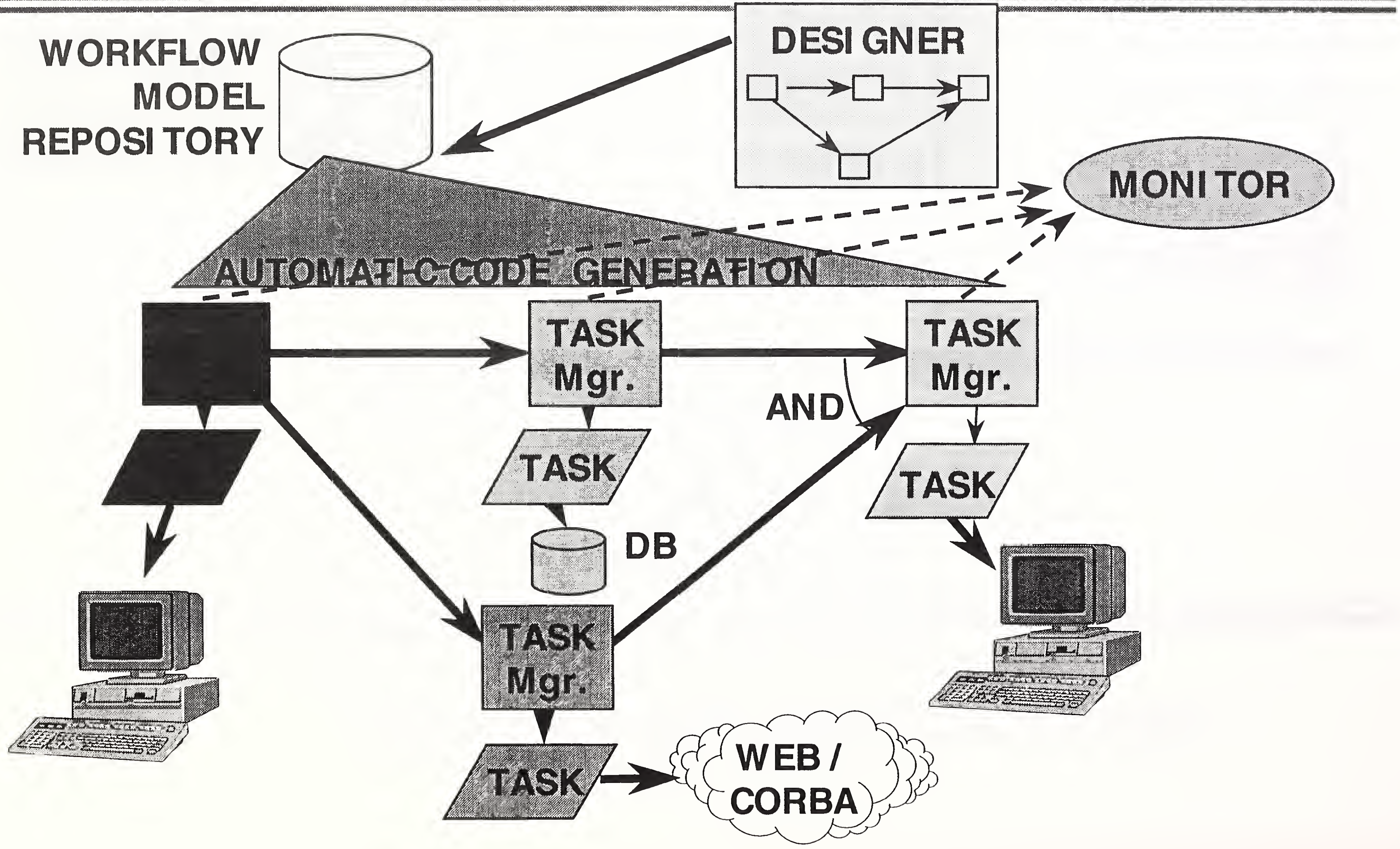
METEOR
Workflow Management System

An example WfMS for mission-critical, enterprise-wide and inter-enterprise distributed workflow applications

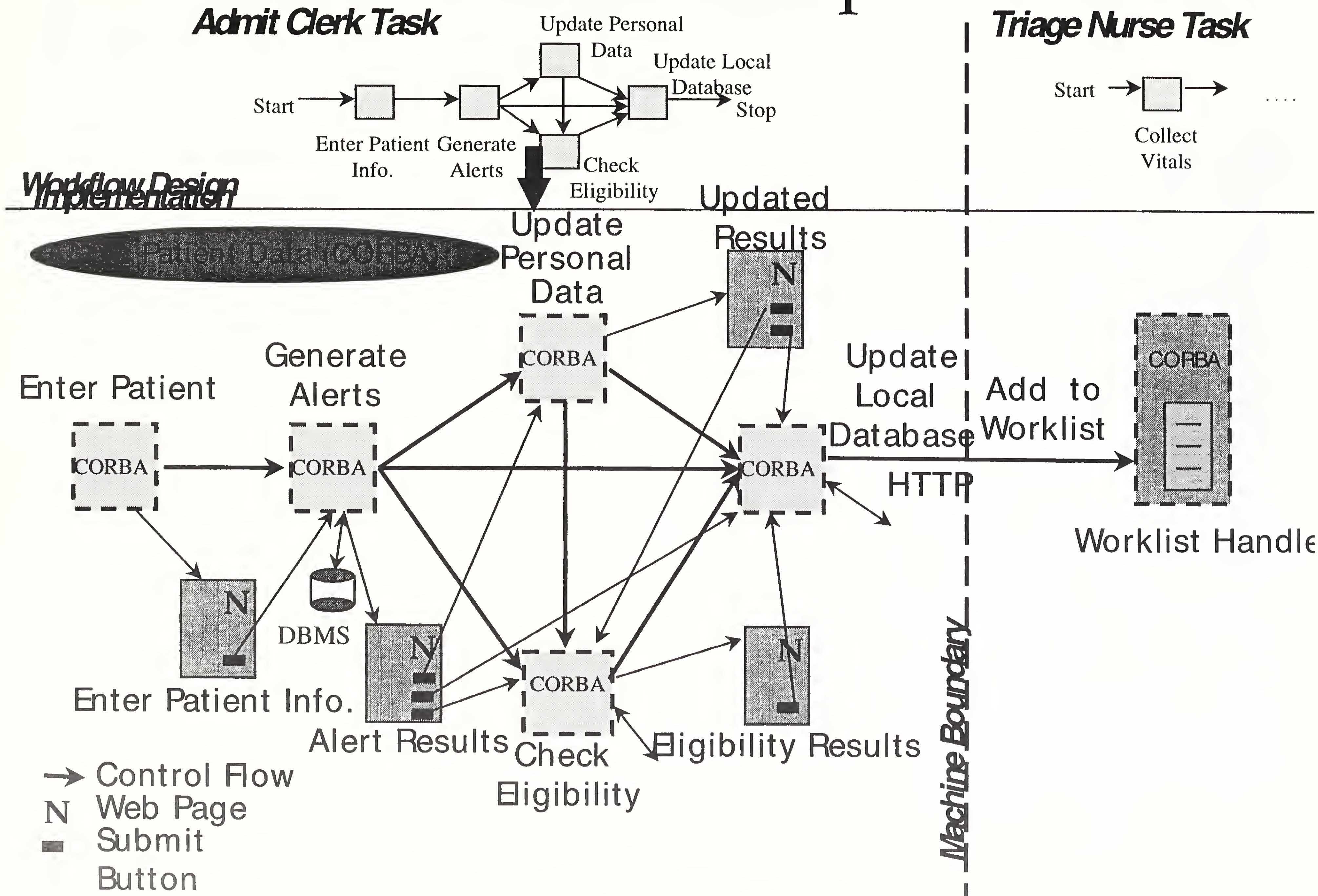
METEOR$_2$ Components



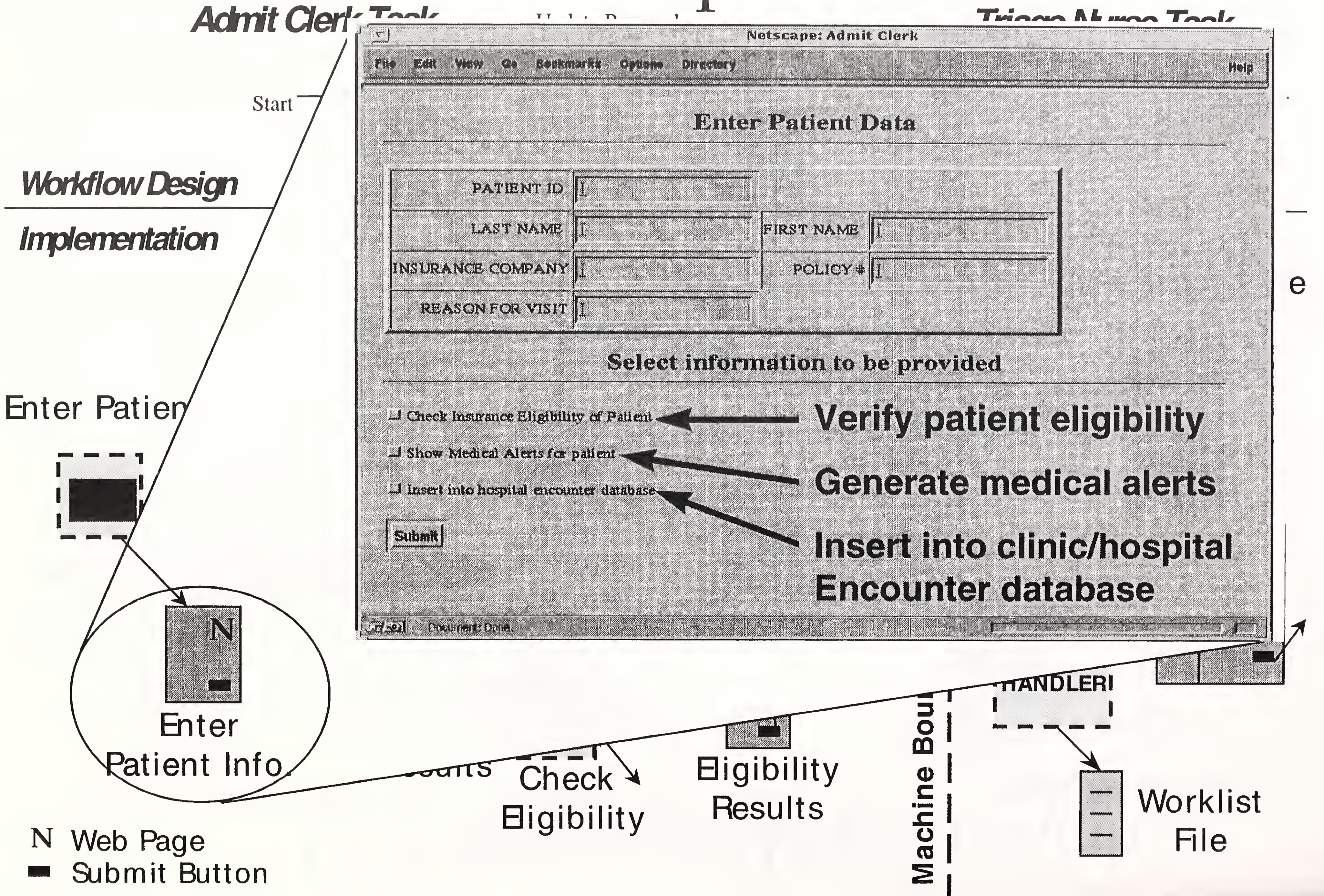
METEOR$_2$ Architecture
(Managing End-to-End OpeRations)



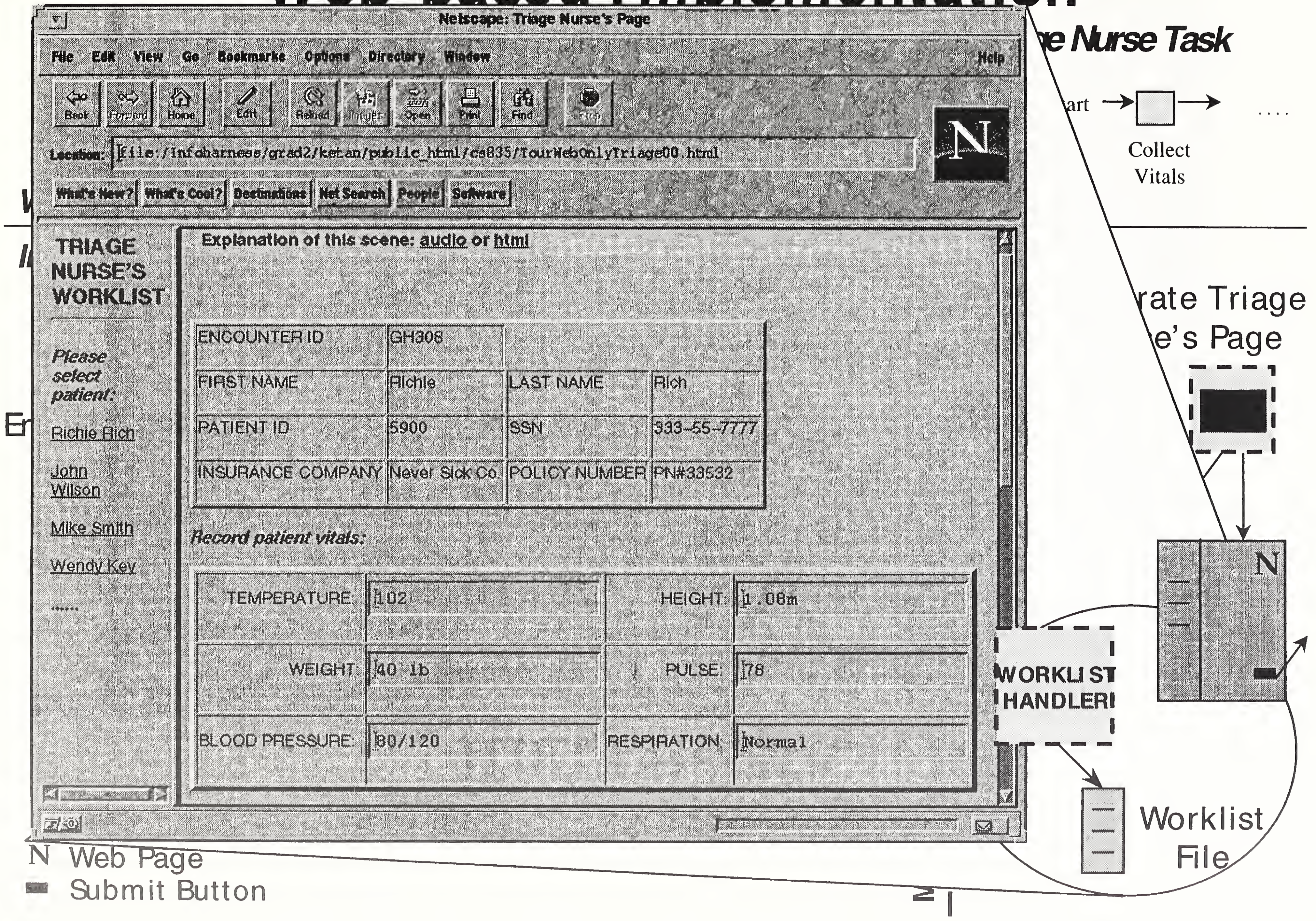
CORBA-based Implementation



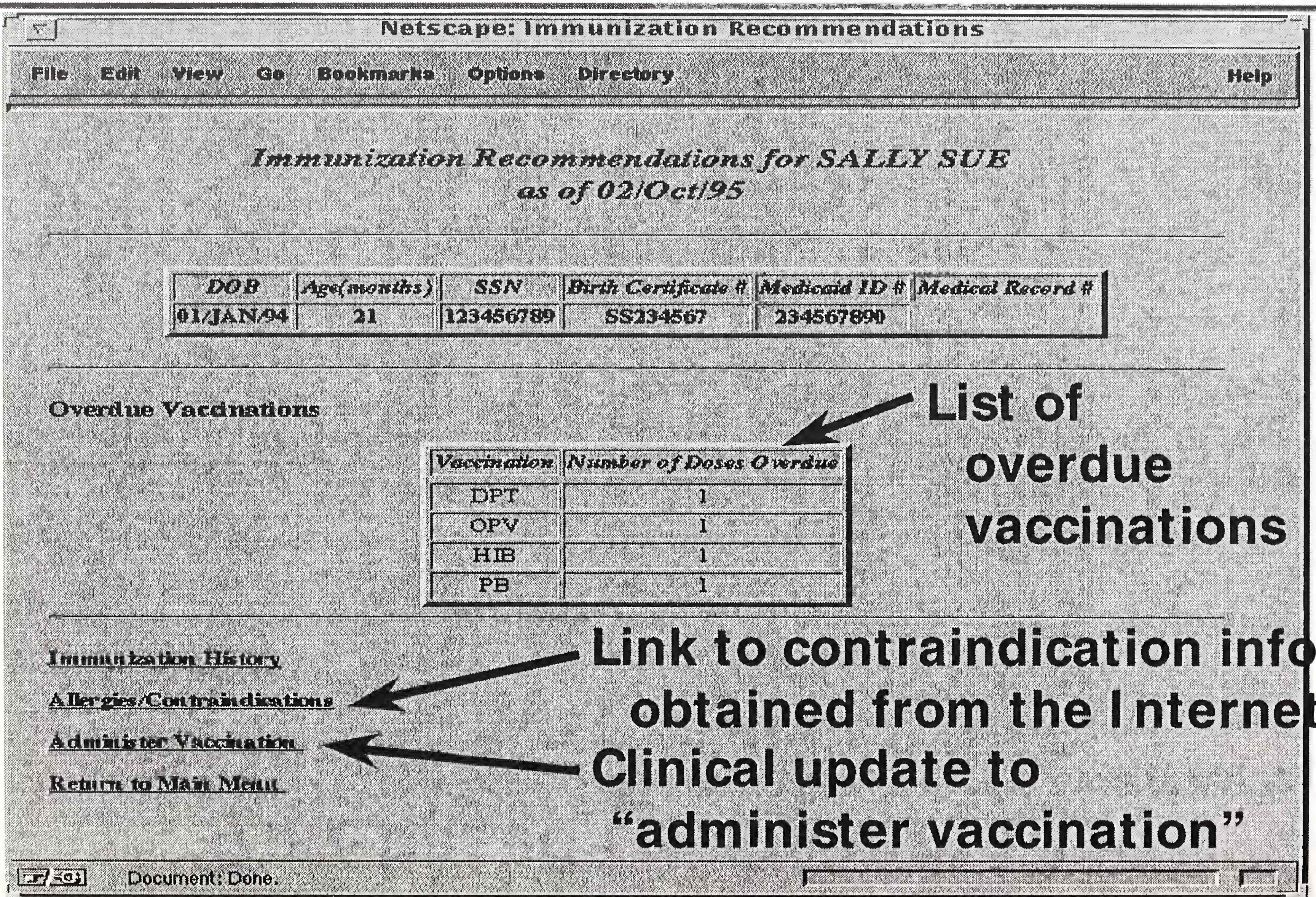
Web-based Implementation



Web-based Implementation



Provider Interface: Immunization Reco's



Web Enabled and Web Based Engines

Web Enabled

Centralized

Web Based Distributed

Front End

Enactment, monitoring, administration

ActionTech

WebFlo

DartFlow

OzWeb

Endeavors

WebWork

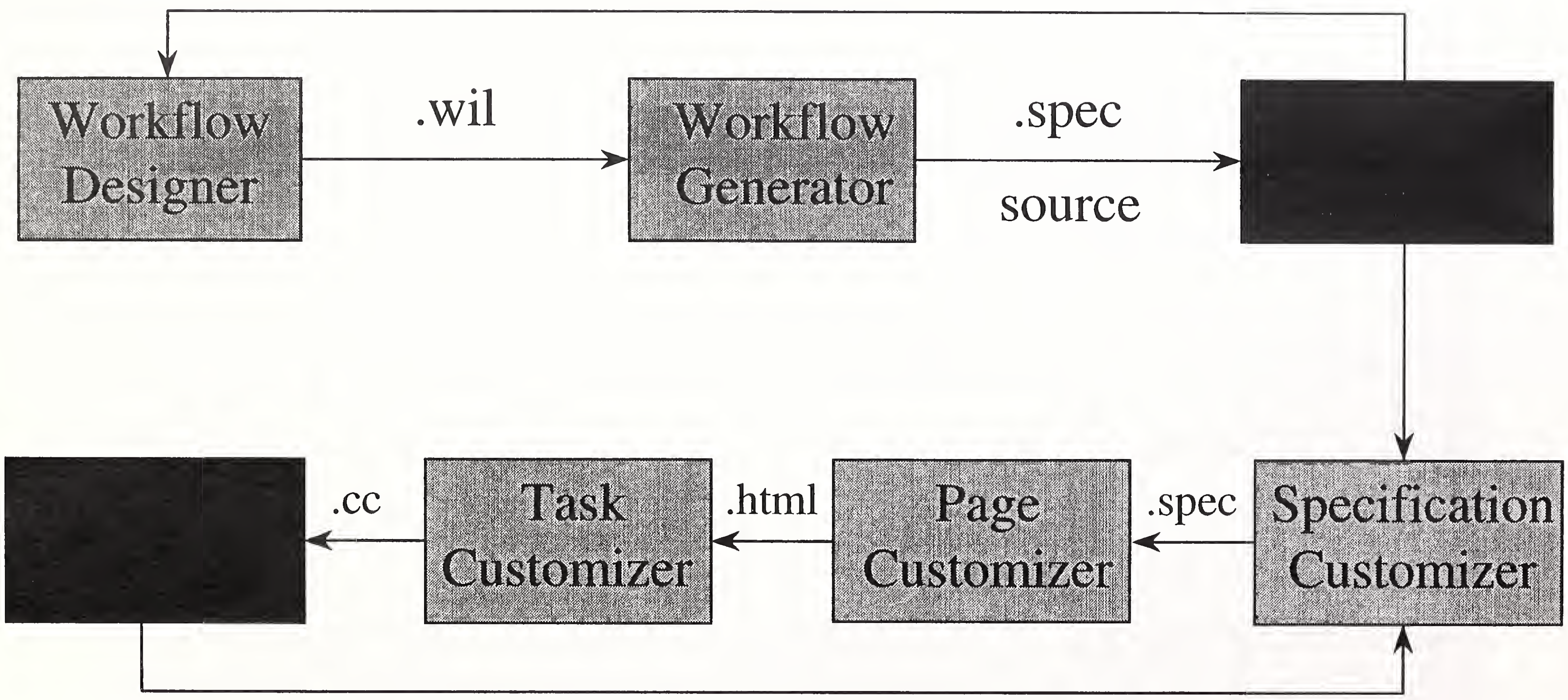
CGI

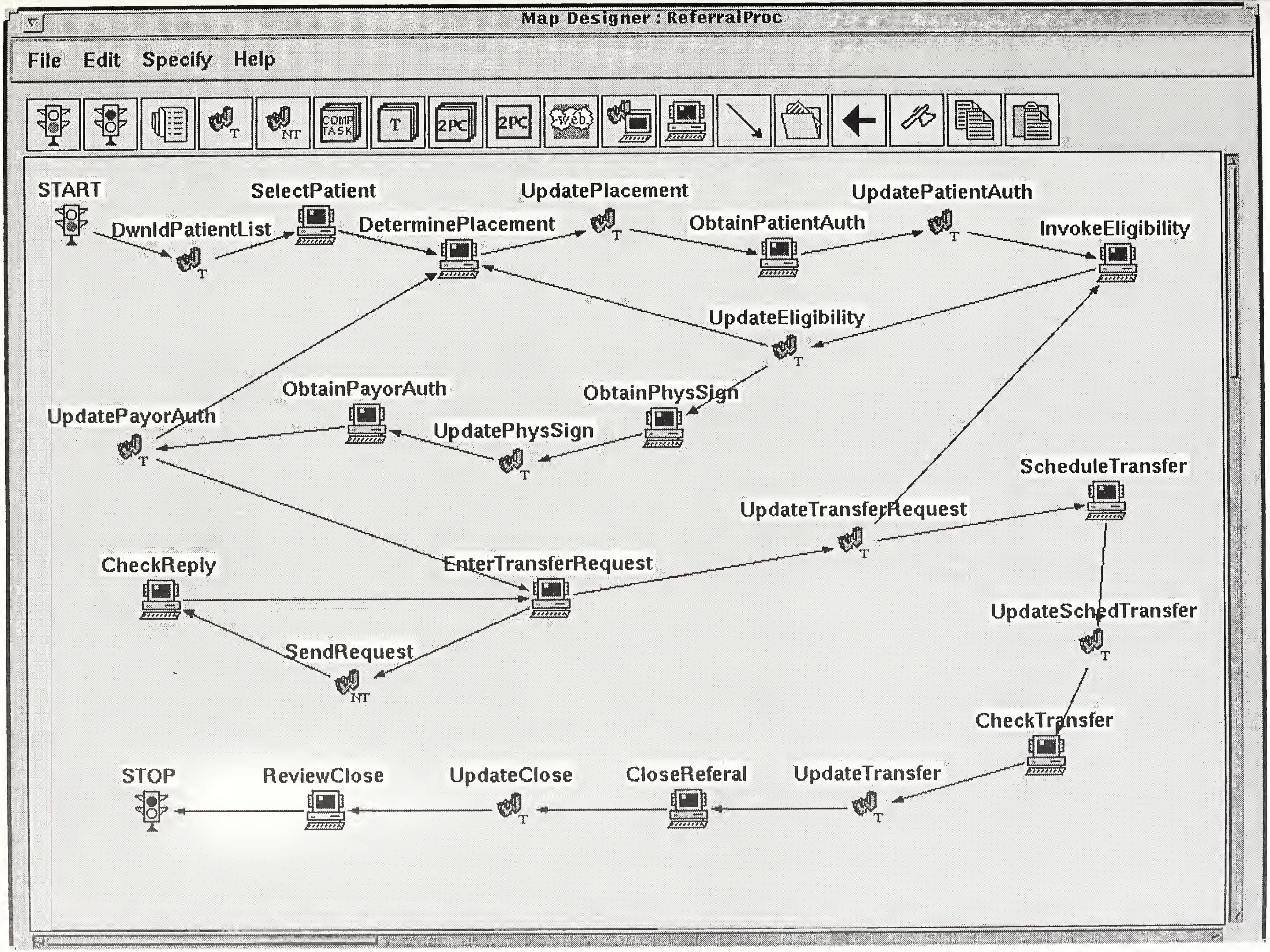
Tcl,Java

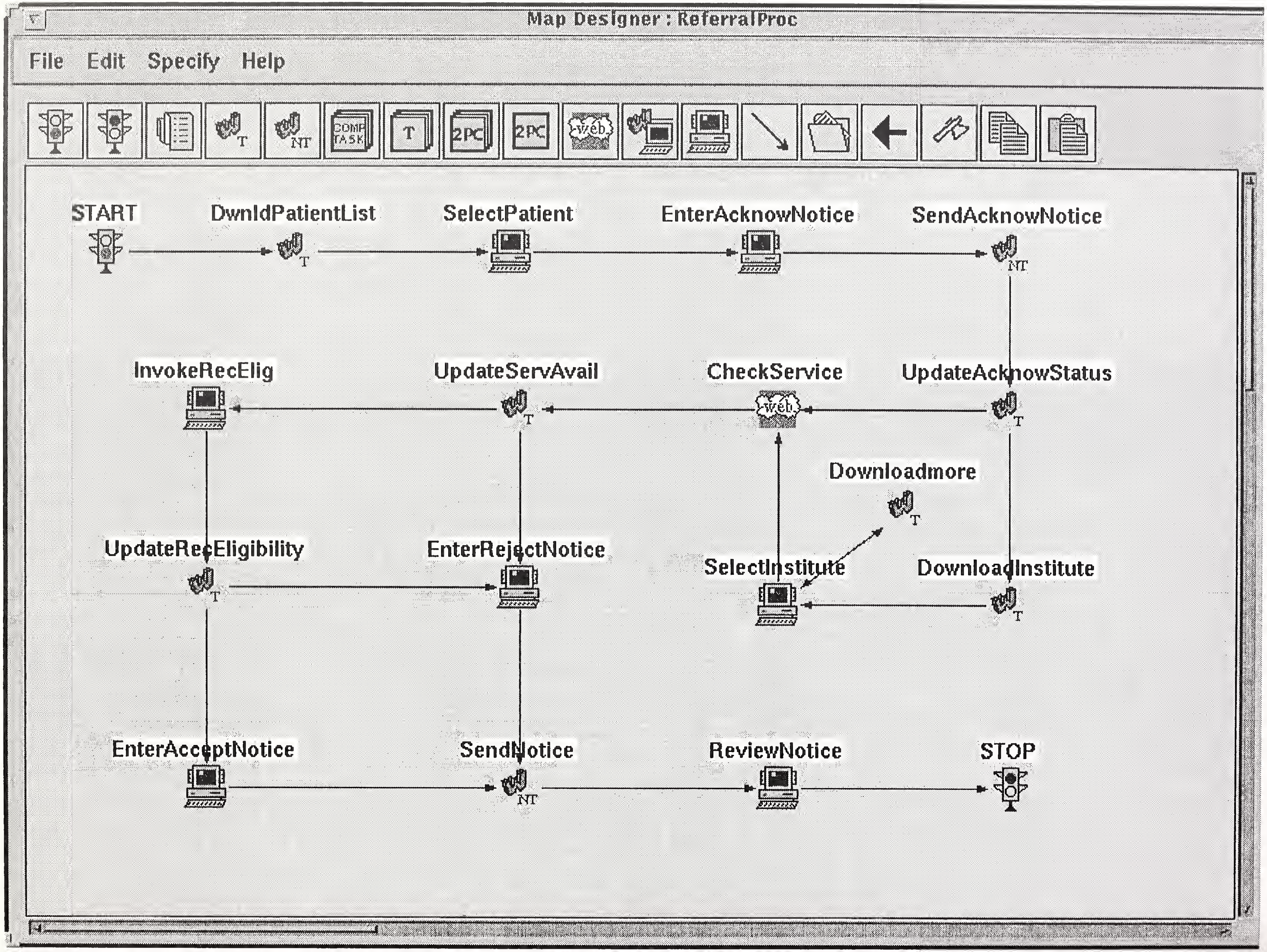
Distributed Scheduling

Error handling
Recovery
(Transactional Support)

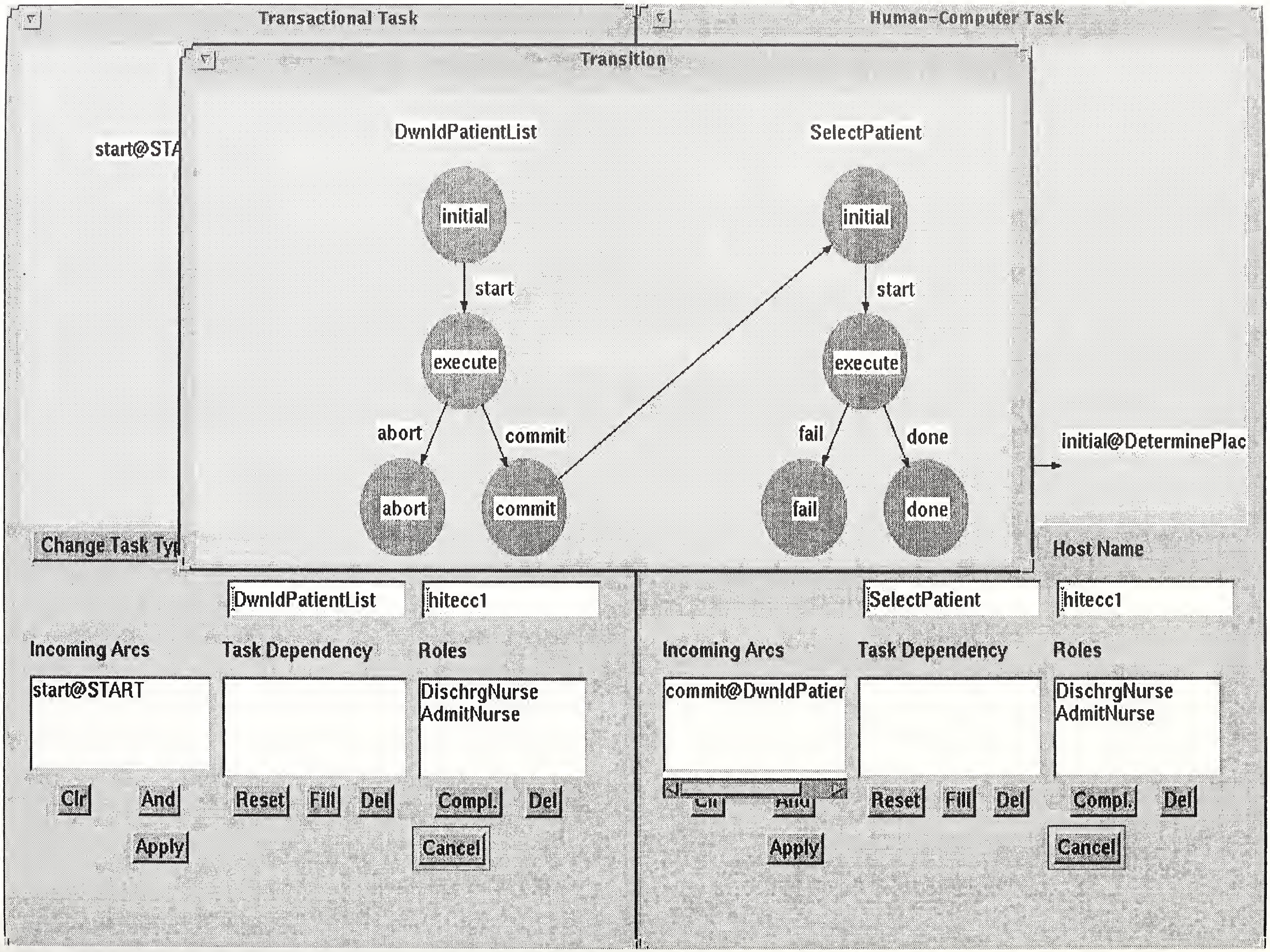
WebWork Application Development

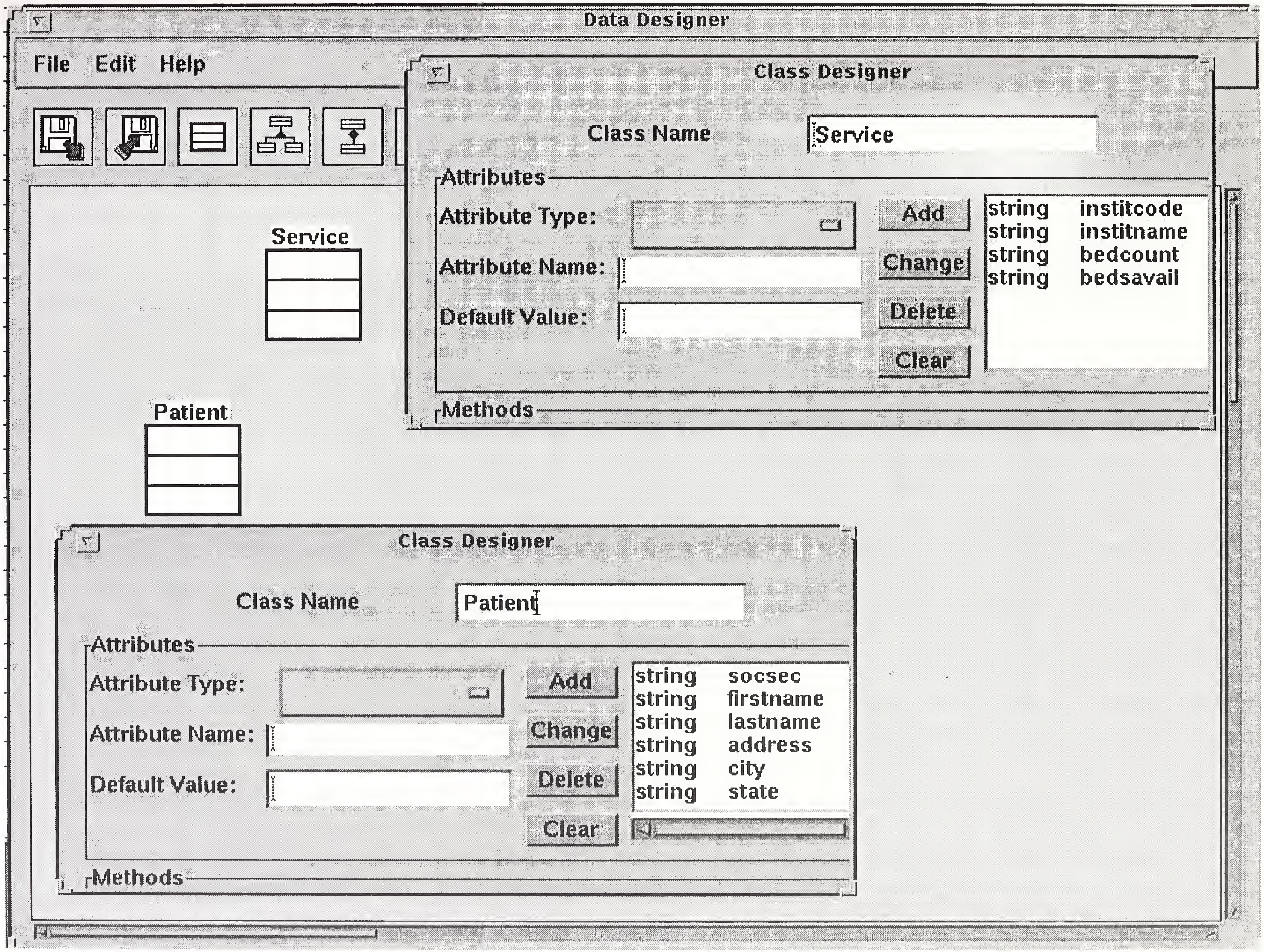



Map Designer : ReferralProc
File
Edit
Specify
Help
START
DwnldPatientList
SelectPatient
DeterminePlacement
UpdatePlacement
ObtainPatientAuth
UpdatePatientAuth
InvokeEligibility
UpdateEligibility
ObtainPhysSign
UpdatePhysSign
ObtainPayorAuth
UpdatePayorAuth
ScheduleTransfer
UpdateTransferRequest
CheckReply
EnterTransferRequest
UpdateSchedTransfer
SendRequest
CheckTransfer
STOP
ReviewClose
UpdateClose
CloseReferal
UpdateTransfer



Map Designer : ReferralProc
File
Edit
Specify
Help
START
DwnldPatientList
SelectPatient
EnterAcknowNotice
SendAcknowNotice
InvokeRecElig
UpdateServAvail
CheckService
UpdateAcknowStatus
Downloadmore
UpdateRecEligibility
EnterRejectNotice
SelectInstitute
DownloadInstitute
EnterAcceptNotice
SendNotice
ReviewNotice
STOP


Transactional Task
Human-Computer Task
Transition
start@STA
DwnldPatientList
SelectPatient
initial
start
execute
abort
commit
abort
commit
initial
start
execute
fail
done
fail
done
initial@DeterminePlac
Change Task Typ
Host Name
DwnldPatientList
hitecc1
SelectPatient
hitecc1
Incoming Arcs
Task Dependency
Roles
start@START
DischrgNurse
AdmitNurse
Clr
And
Reset
Fill
Del
Compl.
Del
Apply
Cancel
Incoming Arcs
Task Dependency
Roles
commit@DwnldPatier
DischrgNurse
AdmitNurse
Reset
Fill
Del
Compl.
Del
Apply
Cancel

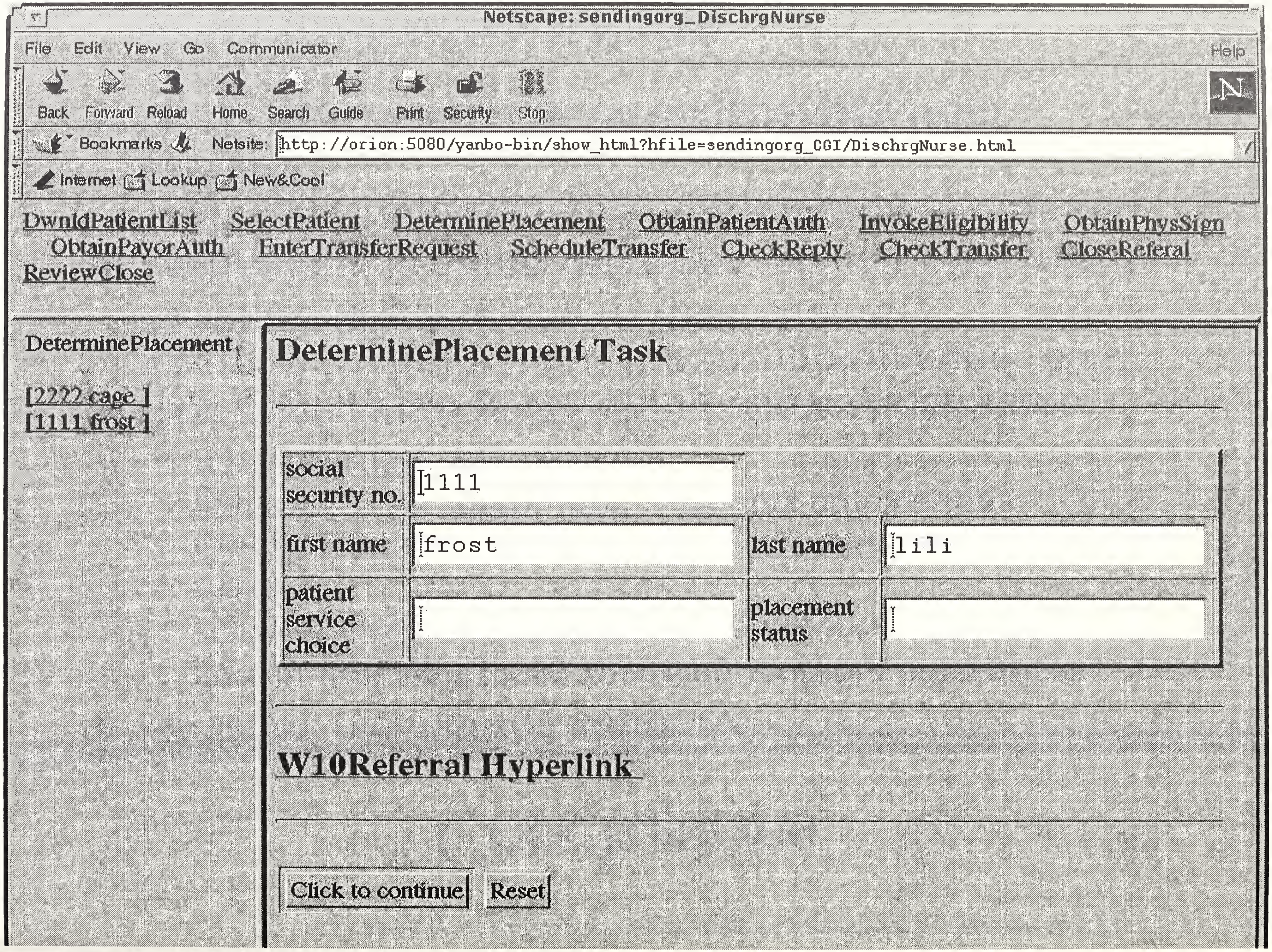

Data Designer
File
Edit
Help
Class Designer
Class Name
Service
Attributes
Attribute Type:
Attribute Name:
Default Value:
Add
Change
Delete
Clear
string institcode
string institname
string bedcount
string bedsavail
Methods
Service
Patient
Class Designer
Class Name
Patient
Attributes
Attribute Type:
Attribute Name:
Default Value:
Add
Change
Delete
Clear
string socsec
string firstname
string lastname
string address
string city
string state
Methods

WebWork Workflow Generator (Rapid Prototype Development)

- make spec
  - » Create WebWork specifications
- make source
  - » Create source code
- make compile
  - » Compile source and link with runtime
- make install
  - » Install CGI executables and HTML files in appropriate cgi-bin directories

Final Development via Customization

- Specification Customizer
  - » Java application to update .spec files
  - » specify DB query, worklist display, etc.
- Page Customizer
  - » HTML (or regular) editor
  - » hide attributes, add fancy page elements, etc.
- Task Customizer
  - » Merge utility to add code to application task


Netscape: sendingorg_DischrgNurse
File Edit View Go Communicator Help
Back Forward Reload Home Search Guide Print Security Stop
Bookmarks Netsite: http://orion:5080/yanbo-bin/show_html?hfile=sendingorg_CGI/DischrgNurse.html
Internet Lookup New&Cool
DwnldPatientList SelectPatient DeterminePlacement ObtainPatientAuth InvokeEligibility ObtainPhysSign ObtainPayorAuth EnterTransferRequest ScheduleTransfer CheckReply CheckTransfer CloseReferal ReviewClose
DeterminePlacement
[2222 cage]
[1111 frost]
DeterminePlacement Task
social security no.
1111
first name
frost
last name
lili
patient service choice
placement status
W10Referral Hyperlink
Click to continue
Reset

Conclusions

- METEOR technology supports - -
  - » Distributed workflows spanning multiple enterprises
  - » Heterogeneous computing environments with variety of tasks
  - » Comprehensive design/ build toolkit with automated code generation for distributed workflow applications
  - » Error handling and recovery
- Real application prototyping allows healthcare partners to understand the technology and "sell" workflow applications to their clients
- Technology is being validated against real- world healthcare requirements; more implementations planned
- METEOR software can be sublicensed from Infocosm, Inc;
  support/ consulting available